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† In marine separate.

CORRECTION

REVIEW, APRIL, 1924:

Page 217, Table 1, in the second column, opposite 150, the true velocity printed as 133.8 *should be* 113. 8.

MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

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RECORDS OF TOTAL SOLAR RADIATION INTENSITY AND THEIR RELATION TO DAYLIGHT INTENSITY [1]

By HERBERT H. KIMBALL

Weather Bureau, Washington, November, 1924

SYNOPSIS

In this paper an attempt is made to ascertain with what degree of accuracy records of the total radiation, or heat energy, received on a horizontal surface directly from the sun and diffusely from the sky, may be used to determine the intensity of daylight illumination on a horizontal surface. The utility of this investigation is obvious, since continuous records of the total radiation received on a horizontal surface are now obtained by the Weather Bureau at some of its more important stations, and electric-lighting companies are employing methods involving heat energy measurements in determinations of the variability of daylight.

From Abbot's normal solar energy curve, and atmospheric transmission coefficients for different wave lengths of light also due to Abbot, the ordinates have been computed for solar energy curves in atmospheres of different degrees of transparency, and with the sun at different zenith distances.

The ordinates of energy curves for a Planckian distribution at temperatures corresponding to color-temperatures of skylight measured by Priest and others have also been computed, and combined with the ordinates of the solar energy curve to determine the energy distribution in the total radiation received on a horizontal surface. The results indicate that midday radiation is richer in luminous rays than the radiation that is received when the sun is near the horizon.

Comparisons between photometric measurements of daylight and pyrheliometric measurements of the total radiation lead to the same result. They indicate, however, that if the radiation intensity on a horizontal surface, expressed in gram-calories per minute per cm.,^{2} is multiplied by 6,700, the result will give the illumination intensity on a horizontal surface in foot-candles within $\pm$ 5 per cent, giving values which near noon are too low and which are too high when the sun is near the horizon.

INTRODUCTION

In cooperation with the Illuminating Engineering Society of America, the Weather Bureau has made an extensive study of the intensity of direct sunlight, diffuse skylight, and the total daylight, upon horizontal surfaces, and upon vertical and sloping surfaces differently oriented with respect to the sun.[2]

Recently the Illuminating Engineering Society has asked that methods of daylight recording be considered. The present paper is offered as a contribution to this subject.

RECORDS OF SOLAR RADIATION INTENSITY

Several instruments are now available for obtaining continuous records of solar radiation intensity. One of the best known is the Callendar differential pyrheliometer, in the form of black and bright resistance grids, which when shaded have equal resistances, but when exposed to sunlight show a temperature difference and a resulting difference in resistance. This difference in resistance between the two grids is continuously recorded on a chart by means of a self-adjusting Wheatstone bridge. The excess in the resistance of the black grids over that of the bright grids is nearly proportional to the intensity of the radiation to which the grids are exposed.

Recently thermopiles have been extensively used for recording solar radiation intensities. The Ångström,[3] the Moll,[4] and the Weather Bureau[5] thermoelectric recording pyrheliometers are examples of instruments of this type. The electromotive force generated by the thermopiles, when so exposed that one junction is heated and the other remains at about the temperature of its environment, is nearly proportional to the intensity of the radiation to which they are exposed. The desired temperature difference may be obtained by blackening the receiving surface to which one set of junctions is attached and painting the other white, as in the Weather Bureau instrument, or by painting both sets of junctions black, attaching one set to heavy posts that will conduct away the heat received by radiation, and leaving the other free.

Thermopiles thus prepared are equally sensitive to practically all wave lengths of light found in the solar spectrum. This is not true of the sensitivity of the human eye to sunlight, as is shown by the curved lines of Figure 1.

In this figure, I is a reproduction of Abbot's normal solar energy curve for zero atmosphere.[6] From this curve I have computed Curves II, III, IV, and V, showing the solar energy distribution with average atmospheric transmission for Washington, D. C.,[7] and with solar zenith distances 25°, 60°, 70.7°, and 78.7°, which latter correspond to air masses 1.1, 2.0, 3.0, and 5.0, respectively.

Curve VI gives the Illuminating Engineering Society curve of relative visibility of radiation.[8] We note at once that the maximum of Curve VI falls, with respect to the wave length of light, between the maxima of Curves II and III. That is to say, the wave length of light to which the eye is most sensitive is the wave length of the maximum of the solar energy curve for Washington, with average atmospheric transmission, when the sun is at about zenith distance, 48°, or approximately at noon on March 1 and October 15. Since, however, the atmospheric transmission in the Northern Hemisphere is greater in winter than in summer, and greater in high latitudes than in low latitudes, we may say, in general, that the wave length of light to which the eye is most sensitive is the wave length of the maximum of

[1] Read before section A (cosmical physics subsection), British Association for the Advancement of Science; Toronto, August 11, 1924; and before the Annual Convention of the Illuminating Engineering Society of America, Briarcliff Manor, N. Y., on October 28, 1924. Slight revisions have been made in the text as here printed.

[2] Kimball, Herbert H., and Hand, Irving F., Sky Brightness and Daylight Illumination Measurements. MO. WEATHER REV., September, 1921, 49:481–488; Trans. Illuminating Eng. Soc., Oct. 10, 1921, 16:255–283.
Daylight Illumination on horizontal, vertical, and sloping surfaces. MO. WEATHER REV., December, 1922, 50:615–628; Trans. Illuminating Eng. Soc., May, 1923, 18:434–474.
Kimball, Herbert H., The determination of daylight intensity at a window opening. Trans. Illuminating Eng. Soc., March, 1924, 19:217–234.

[3] Ångström, A., and Dorno, C., Registration of the intensity of sunshine and diffuse sky radiation. MO. WEATHER REV., 1921, 49:135.

[4] Gorczyński, Ladislas, On a simple method of recording the total and partial intensities of solar radiation. MO. WEATHER REV., June, 1924, 52:299–301.

[5] Kimball, Herbert H., and Hobbs, Herman E., A new form of recording thermoelectric pyrheliometer. MO. WEATHER REV., May, 1923, 51:239–242; Jour. Opt. Soc. Amer. & Rev. Sci. Insts., September, 1923, 29:707–718.

[6] Abbot, C. G., Fowle, F. E., and Aldrich, L. B., The distribution of energy in the spectra of the sun and stars. Smithsonian Misc. Coll., vol. 74, No. 7, fig. 1.

[7] Annals of the Astrophysical Observatory of the Smithsonian Institution, 3:135.

[8] Illuminating Eng. Nomenclature and photometric standards. Trans. Ill. Eng. Soc., December, 1918, vol. 13, p. 512.

the solar energy curve at noon in the North Temperate Zone.

In this connection it is of interest to note that the absolute monthly maxima of solar-radiation intensity measured at Washington, D. C., have varied between 1.43 gram-calories per minute per cm.² in January, June, and August, and 1.51 in April and October, or 5.3 per cent. Reduced to mean solar distance, the range of these maxima is from 1.39 gr.-cal. in January to 1.52 in July, or 8.6 per cent.

THE COLOR TEMPERATURE OF DAYLIGHT

The curves of Figure 1 clearly indicate that on a given day, with increase in the zenith distance of the sun, the maximum of the solar energy curve will fall at increasingly longer wave lengths of light, or more and more towards the red end of the spectrum. Priest [9] has measured this variation in terms of color temperature, which he defines as follows: [10]

> The color temperature of a source is the temperature at which a Planckian radiator would emit radiant energy competent to evoke a color of the same quality as that evoked by the radiant energy from the source in question.

In Figure 2, I have plotted against air mass the logarithms of his measured color temperatures of direct sunlight obtained at the Bureau of Standards on February 20, 1920, and have drawn free hand the curve of best fit to his a. m. and p. m. observations.

During the morning of this day pyrheliometric measurements of the solar radiation intensity were made by the Weather Bureau at the American University, only about a mile from the Bureau of Standards. The intensities at air masses 3.0, 2.5, 2.0, and 1.5 were 0.82, 0.91, 1.04, and 1.15, respectively, which are low values for these air masses in February, but not far from the average for the year. Haze was recorded at the time the radiation intensity was measured, and fracto-cumulus clouds commenced to form before noon. The atmospheric transmission coefficient was about 0.78, but varied markedly from time to time.

The logarithms of color temperatures in Figure 2 follow closely a line concave upward, as is usually the case with the logarithms of radiation intensities. The tangents to the curve between air masses 2 and 3, 3 and 4, and 4 and 5, are 0.898, 0.905, and 0.910, respectively.

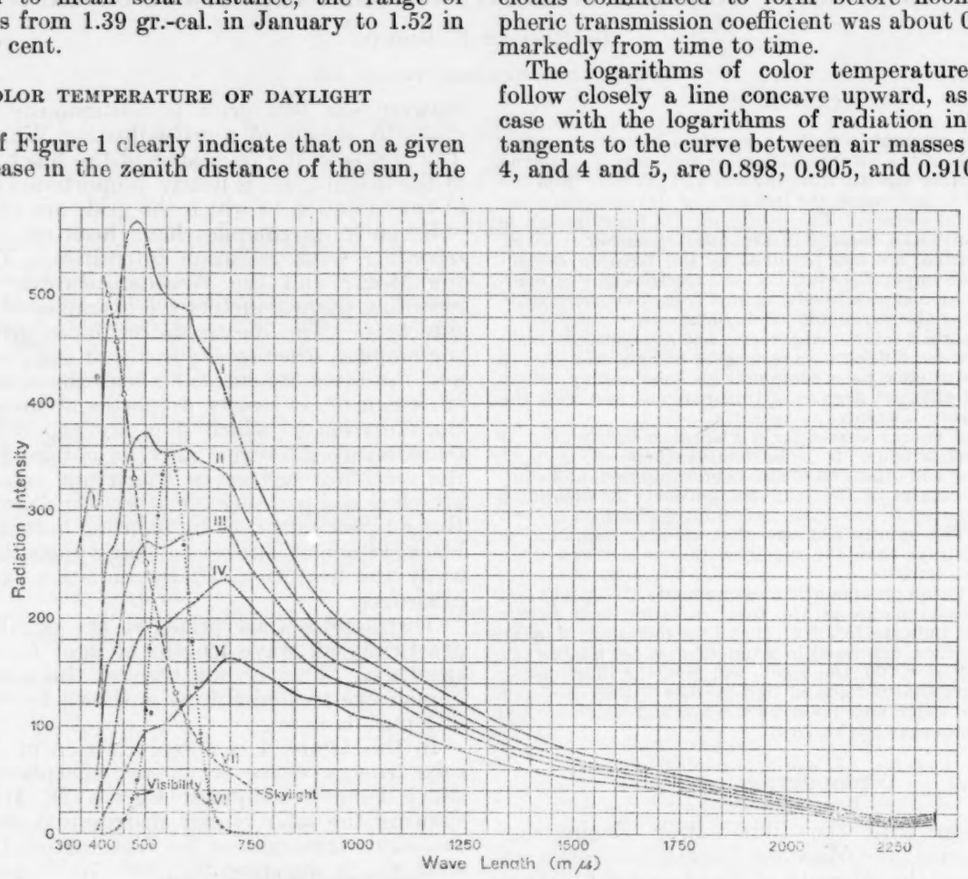

FIG. 1.—Energy distribution curves:
Curve I. Normal solar energy curve outside the atmosphere (m=0).
Curve II. Solar energy curve. Solar zenith distance=25° (m=1.1).
Curve III. Solar energy curve. Solar zenith distance=60° (m=2.0).
Curve IV. Solar energy curve. Solar zenith distance=70.7° (m=3.0).
Curve V. Solar energy curve. Solar zenith distance=78.7° (m=5.0).
Curve VI. Relative visibility of radiation.
Curve VII. Sky light energy curve, Mount Wilson, Calif.

The change in color temperature with air mass is therefore much slower than the change in radiation intensity.

The variation in color temperature is from 1700° K 15 minutes after sunrise, to 5400° K at midday. Extrapolation to zero air mass gives 6500° K. Measurements for June 26, 1922,[11] also plotted in Figure 2, vary between 5300° K 25 minutes after solar noon, and 4510° K at 4:46 p. m., with increasing haziness during the afternoon. The above indicated decrease in the color temperature of direct sunlight with increase in the solar zenith distance shows that we can not expect a constant ratio between radiation intensities and the intensity of direct sunlight. In fact, it has already been shown [12] that the illumination equivalent of 1 gr. cal./min./cm.² varies between 7,040 foot-candles with solar zenith distance 20°, and 6,320 foot-candles with solar zenith distance 79.8°.

[9] Priest, Irwin G., A new study of the Leucoscope and its application to pyrometry. VI. Experiments on Leucoscopic determination of the quality of sunlight and its diurnal variation. Jour. Optical Soc. of Amer. 4:480-484.

[10] Priest, Irwin G., The Colorimetry and Photometry of Daylight and Incandescent Illuminants. Jour. Opt. Soc. Amer. & Rev. Sci. Inst. 7, p. 1180, December, 1923.

[11] Jour. Opt. Soc. Amer. and Review of Scientific Instruments, 1923, 7: 78.

[12] Kimball, Herbert H. and Hand, Irving F., Daylight Illumination on Horizontal, Vertical, and Sloping Surfaces. MO. WEATHER REV., 1922, 50: 622, Table 6.

THE QUALITY OF DAYLIGHT

We are interested not so much in the color temperature of direct sunlight, however, as in the quality of the total daylight, which is made up partly of direct sunlight and partly of diffuse light from the sky. Table 1 shows the ratio of direct solar radiation to diffuse sky radiation as measured on a horizontally exposed surface at various places and by different observers. At Washington, D. C., the measurements were made with the thermoelectric pyrheliometer; at Madison, Wis., and Lincoln, Nebr., with the Callendar recording pyrheliometer.[13] The measurements at Flint Island, and Mount Wilson and Mount Whitney, Calif., were made by the Smithsonian Institution with the bolometer.[14] Those at Hump Mountain, N. C., were made by the Smithsonian Institution[15] with the pyranometer, and do not seem to be in accord with the other measurements, since they show too little sky radiation.

It will be seen that the ratios of Table 1 increase with height above sea level, and decrease as the solar zenith distance increases. With the sun within a few degrees of the horizon more radiation may be received on a horizontal surface diffusely from the sky than directly from the sun. The Washington ratios show a marked seasonal variation, having a maximum in winter and a minimum in summer.

TABLE 1.—*Ratio of direct solar radiation received on a horizontal surface to diffuse sky radiation*

	Solar zenith distance												
	7.5°	25°	30°	48.3°	55°	60°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	85.0°
Washington, D.C.:													
Winter	----	----	----	7.02	----	5.18	4.02	3.36	2.97	2.48	2.11	1.70	----
Spring	----	8.72	----	6.53	----	4.87	3.91	3.10	2.56	2.14	1.83	1.53	----
Summer	----	4.25	----	3.76	----	3.18	2.72	2.25	1.96	1.71	1.64	1.50	----
Mean of all	----	5.31	----	4.81	----	4.12	3.41	2.79	2.39	2.05	1.81	1.60	----
Lincoln, Nebr.	----	5.67	----	5.25	----	4.26	3.76	3.17	2.70	2.33	2.03	1.86	----
Madison, Wis.	----	5.25	----	5.25	----	3.17	3.00	2.85	1.94	1.78	----	----	----
Flint Island	----	[1] 4.17	----	----	----	----	----	----	----	----	----	----	----
Hump Mountain	----	----	----	11.00	----	8.97	7.19	6.78	5.52	5.33	4.69	4.13	----
Mount Whitney	----	12.25	----	----	----	----	----	----	----	----	----	----	----
Mount Wilson	6.27	[2] 6.10	6.00	5.08	4.13	[3] 3.90	3.23	[3] 2.70	----	2.12	----	[3] 1.62	0.82

[1] Solar zenith distance=18.6°. [3] Interpolated values.

Abbot has determined the energy curve for skylight on Mount Wilson,[16] and it is reproduced as Curve VII of Figure 1. It shows the excess of radiation of short wave length in diffuse radiation from the sky as compared with direct solar radiation.

Priest [17] and some others have also measured the color temperature of skylight, and have found it to vary when no clouds are present from about 6000° K to 24000° K. With thin clouds the color temperature sometimes dropped below 7000° K and with a uniformly overcast sky to 6300° K.

Knowing the color temperature of radiation, we may reproduce approximately its spectrum energy curve, and knowing the ratio between the intensity of direct solar and diffuse sky radiation we may express the energy of both for different wave lengths in the same units.

Abbot's energy curve for sky light at Mount Wilson approximates the Planckian energy distribution [18] for a temperature of slightly over 50000° K. This seems high, but Priest obtained a color temperature for sky light at Washington on the morning of November 30 and near noon December 28, 1921, of 24150° K. It is well known that the average sky at Mount Wilson is much bluer than is even the clearest sky at Washington. On November 30, 1921, the solar radiation intensity at Washington with the sun 11.3° above the horizon, corresponding to air mass 5.0, was 0.69 gr. cal, as compared with a normal at this air mass for November of 0.76. On December 28, 1921, at noon, solar radiation intensities were nearly 6 per cent above the normal for this hour in December. The polarization of sky light was 65 per cent as compared with an average for December of 59 per cent.

In general, however, the color temperature of sky light during the summer months, in the absence of clouds, appears to have varied between 8000° and 15000° K. Measurements on June 30, 1922, a hazy day with solar radiation intensities much below the average for June, give sky light color temperatures of from 8080° to 9950° K.

Abbot's bolometric measurements at Washington were made only on days with exceptionally clear skies. Curves

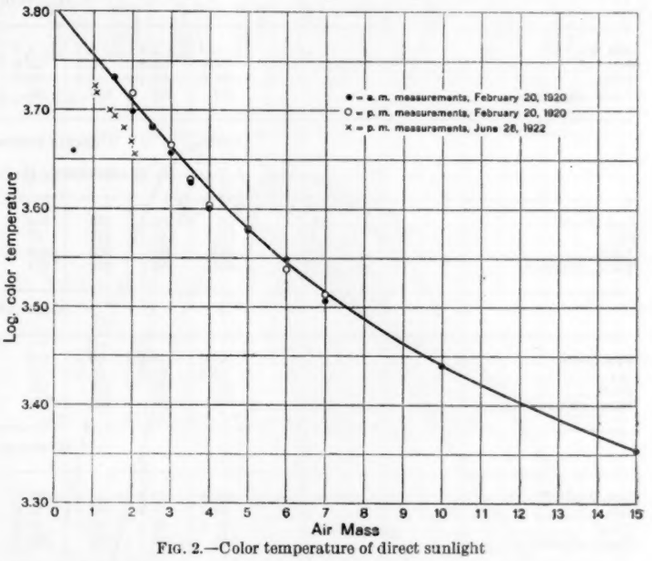
3.80
3.70
3.60
3.50
3.40
3.30
Log. color temperature
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Air Mass
● = a. m. measurements, February 20, 1920
○ = p. m. measurements, February 20, 1920
× = p. m. measurements, June 28, 1922

FIG. 2.—Color temperature of direct sunlight

II to V, Figure 1, therefore, represent the mean solar energy distribution for exceptionally clear days throughout the year.

In Table 2 (b) there is given in the line headed "Sun, Z=25°, Z=60°, " etc., the intensity of solar radiation at selected wave lengths in the visible spectrum, obtained from Curves II, III, IV, and V, Figure 1, by multiplying the ordinates of these curves at the selected wave lengths by the cosines of the solar zenith distances for which the respective curves have been computed.

By a similar process the vertical components of solar radiation intensity have been computed for May 14, 1907, at Washington, a day with a hazy sky, for February 15, 1907, at Washington, an unusually clear day, and for an average day at Mount Wilson, Calif. (See Table 2 (a), (c), and (d).)

[13] MO. WEATHER REV., August, 1914, **42**: 474–489: 1924, **52**: 42.
[14] Annals of the Astrophysical Observatory, **3**: 141–151.
[15] Moore, A. F. and Abbot, L. H., The Brightness of the Sky. Smithsonian Misc. Coll., vol. 71, No. 4.
[16] Annals of the Astrophysical Observatory, **2**: 155.
[17] Jour. Opt. Soc. Amer., 1920, **4**: 483; 1923, **7**: 78, 1184.

[18] Distribution according to Planck's formula:

$$E=c_1\lambda^{-5}\left(\frac{c_2}{e^{\lambda T}-1}\right)^{-1}$$ in which $c_2=14{,}350$ micron-degrees.

The value of c_1 does not affect the distribution.

TABLE 2.—*Energy distribution in the visible spectrum of sunlight and sky light, as received on a horizontal surface, with the sun at different zenith distances, Z*

	WAVE LENGTH, mμ														
	397	413	431	452	475	503	535	556	574	591	624	653	686	720	764
(a) WASHINGTON, D. C., MAY 14, 1907—SKY HAZY															
Sun, Z=25°	101	205	226	254	292	300	288	303	296	302	296	289	279	257	230
Sky	135	127	117	109	99	90	81	72	68	63	56	49	44	38	32
Total	236	332	343	363	391	390	369	375	364	365	352	338	323	295	262
Total, adjusted	126	177	183	194	208	208	197	200	194	195	188	180	177	157	140
(Curve of about 6000° K)															
Sun, Z=60°	22.0	60.0	73.0	80.5	100	110	108	122	117	122	124	124	122	114	104
Sky	78.7	74.7	68.8	63.7	58	53	47	42	40	37	33	29	26	22	19
Total	101	135	142	144	158	163	155	164	157	159	157	153	148	136	123
Total, adjusted	123	165	173	176	193	199	189	200	192	194	192	187	181	166	150
(Curve of about 6000° K)															
Sun, Z=70.7°	5.3	19.9	26.5	28.8	40.1	46.0	47.0	56.3	53.6	56.9	59.9	62.2	61.9	59.6	54.9
Sky	58.8	55.8	51.4	47.6	43.5	39.4	35.3	31.5	30.0	27.8	24.6	21.8	19.2	16.7	14.2
Total	64.1	75.7	77.9	76.4	83.6	85.4	82.3	87.8	83.6	84.7	84.5	84.0	81.1	76.3	69.1
Total, adjusted	146	172	177	174	190	195	188	200	190	193	193	191	185	174	157
(Curve of about 6000° K)															
Sun, Z=78.7°	0.4	2.9	4.7	4.9	8.4	11.0	12.0	16.5	15.3	17.1	19.2	21.2	21.8	22.1	21.0
Sky	34.5	32.8	30.2	28.0	25.6	23.2	20.7	18.5	17.6	16.3	14.4	12.8	11.3	9.8	8.3
Total	34.9	35.7	34.9	32.9	34.0	34.2	32.7	35.0	32.9	33.4	33.6	34.0	33.1	31.9	29.3
Total, adjusted	199	204	199	188	194	195	187	200	188	191	192	194	189	182	167
(Curve of between 5000° and 6000° K)															
(b) WASHINGTON, D. C., AVERAGE CLOUDLESS SKY															
Sun, Z=25°	151	235	249	305	333	338	322	322	322	325	316	310	304	277	248
Sky	135	125	113	97	84	73	62	53	49	46	38	33	27	25	20
Total	286	360	362	402	417	411	384	375	371	371	354	343	331	302	268
Total, adjusted	153	192	193	214	222	220	204	200	198	198	189	183	177	161	143
(Curve of about 6000° K)															
Sun, Z=60°	46.0	78.0	86.5	112	128	136	132	134	136	139	140	140	142	131	119
Sky	80.3	74.1	66.9	58	50	43	37	31	29	27	22	20	16	15	12
Total	126	152	153	170	178	179	169	165	165	166	162	160	158	146	131
Total, adjusted	153	185	186	206	216	217	205	200	200	201	202	194	192	177	159
(Curve of about 6000° K)															
Sun, Z=70.7°	15.9	29.5	34.4	47.7	57.3	63.2	63.2	65.5	67.2	69.8	72.2	75.5	77.8	73.8	67.9
Sky	64.7	59.7	53.9	46.6	40.3	34.8	29.7	25.2	23.4	21.9	18.1	15.9	13.1	11.8	9.8
Total	80.6	89.2	88.3	94.3	97.6	98.0	92.9	90.7	90.6	91.7	90.3	91.4	90.9	85.6	77.7
Total, adjusted	158	197	195	208	215	221	205	200	200	202	199	202	200	189	171
(Curve of about 6000° K)															
Sun, Z=78.7	2.6	5.7	7.4	11.6	15.3	18.6	19.6	20.8	22.1	23.7	26.1	29.0	31.8	31.4	29.6
Sky	50.9	46.9	42.4	36.6	31.7	27.3	23.4	19.8	18.4	17.2	14.3	12.5	10.3	9.3	7.7
Total	53.5	52.6	49.8	48.2	47.0	45.9	43.0	40.6	40.5	40.9	40.4	41.5	42.1	40.7	37.3
Total, adjusted	204	259	245	237	232	226	212	200	200	201	199	204	208	200	184
(Curve of about 7000° K)															
(c) WASHINGTON, D. C., FEBRUARY 15, 1907															
Sun, Z=60°	92.5	130	130	162	198	192	176	176	176	182	175	176	166	151	138
Sky	74.8	77	59	50	42	35	28	26	23	20	18	15	13	11	9
Total	167	207	189	212	240	227	204	202	199	202	193	191	179	162	147
Total, adjusted	165	205	187	210	238	225	202	200	197	200	191	189	177	160	146
(Curve of about 7000° K)															
Sun, Z=70.7°	45.7	63.6	62.9	82.8	109	106	97.0	98.3	99.0	105	101	106	99.3	91.0	83.7
Sky	68.7	62.3	54.5	46.5	38	32	25.8	23.7	20.9	18	16	14	11.6	10.0	8.3
Total	114	126	117	129	147	138	123	122	120	123	117	120	111	101	92
Total, adjusted	187	207	192	211	241	226	202	200	197	202	192	197	182	166	151
(Curve of about 7000° K)															
Sun, Z=78.7°	15.3	20.4	20 2	29.2	45.1	43.9	40.0	41.4	42.3	46.8	45.9	51.0	47.8	44.5	42.1
Sky	65.6	59.5	52.1	44.4	36.7	30.6	24.7	22.6	20.0	17.7	15.4	13.1	11.1	9.5	8.1
Total	80.9	79.9	72.3	73.6	81.8	74.5	64.7	64.0	62.3	64.5	61.3	64.1	58.9	54.0	50.2
Total, adjusted	253	250	226	230	256	233	202	200	195	202	192	200	184	169	157
(Curve of about 7000° K+)															

TABLE 2.—*Energy distribution in the visible spectrum of sunlight and sky light, as received on a horizontal surface, with the sun at different zenith distances, Z*—Continued

WAVE LENGTH, $m\mu$—Continued

(*d*) MOUNT WILSON, AVERAGE CLOUDLESS SKY

	397	413	431	452	475	503	535	556	574	591	624	653	686	720	764
Sun, Z=25°	217	314	333	396	425	424	401	393	389	393	375	363	345	317	282
Sky	73	60	53	44	37	30	24	22	18	17	14	11	9	8	6
Total	290	374	386	440	462	454	425	415	407	410	389	374	354	325	288
Total, adjusted	140	181	186	212	223	219	205	200	197	198	187	180	171	157	139
(Curve of about 6000° K+)															
Sun, Z=60°	89.5	132	148	180	200	204	197	194	192	196	190	188	182	168	150
Sky	58.5	48	43	35	30	24	20	18	15	13	11	9	7	6	5
Total	148	180	191	215	230	228	217	212	207	209	201	197	189	174	155
Total, adjusted	140	170	180	203	217	215	205	200	196	198	190	186	179	175	147
(Curve of about 6000° K+)															
Sun, Z=70.7°	43.0	64.5	76.4	97.0	112	117	115	113	113	117	115	116	113	106	96.0
Sky	50.5	41.6	36.5	30.4	25	21	17	15	13	12	9	7	6	5	4.6
Total	93.5	106	113	127	137	138	132	128	126	129	124	123	119	111	101
Total, adjusted	146	166	177	199	214	216	206	200	197	202	194	192	186	173	158
(Curve of about 6000° K+)															
Sun, Z=78.7	13.5	21.0	27.8	37.8	46.6	51.7	52.9	52.5	52.5	56.1	56.4	59.4	59.4	57.6	52.9
Sky	45.8	37.7	33.1	27.5	22.9	19.0	15.3	13.7	11.6	10.4	8.6	6.7	5.6	4.9	4.2
Total	59.3	58.7	60.9	65.3	69.5	70.7	68.2	66.2	64.1	66.5	65.0	66.1	65.0	62.5	57.1
Total, adjusted	179	177	184	197	210	214	206	200	194	201	196	200	196	187	173
(Curve of about 6000° K+)															

In Table 2, in the lines headed "Sky," there is given the intensity of sky radiation for the same selected wave lengths as for solar radiation, computed as follows: For May, 1907, the energy distribution has been assumed to correspond to a Planckian energy distribution [19] for a temperature of 10000° K; for average clear skies at Washington, to 16000° K; for February 15, 1907, to 24000° K; for Mount Wilson, 50000° K. The intensity relative to solar radiation intensity has been obtained as follows:

Let A = area under solar energy curves (such as Curves II, III, IV, and V, Figure 1) where the energy is expressed in arbitrary units. Allowance must be made for depletion by water-vapor absorption in the infra-red, and for radiations of both shorter and longer wave lengths than are included under the curves.

Let a' = area under the energy curve for a Planckian energy distribution at the assumed color temperature of sky light, with the energy expressed in arbitrary units, but with the wave-length scale the same as for A. Here, also, allowance must be made for the fading out of the solar spectrum for wave lengths shorter than 350 $m\mu$. It has been assumed that the spectrum of daylight ends, like the solar spectrum, at 290 $m\mu$.

Let R = the ratios between the intensity of solar and sky radiation as given in Table 1.

Let a = the area of a' expressed in the same units as A.

Then $a = A/R$, and to reduce the ordinates of the energy distribution at the assumed color temperature of sky light to the same scale as the ordinates of the solar energy curves, we must multiply them by the ratio a/a'.

The sum of the ordinates for solar and sky energy curves thus obtained gives the intensity of the total radiation at the different wave lengths. For ease of comparison these totals have been adjusted so as to give a value of 200 at wave length 556 $m\mu$. Following these adjusted values, I have indicated the temperature of the

[19] "Tables and graphs for facilitating computations of spectral energy distribution," by Frehafer and Snow, Bureau of Standards Misc. Publication No. 56, have been utilized in determining the distribution for temperatures below 28000° K.

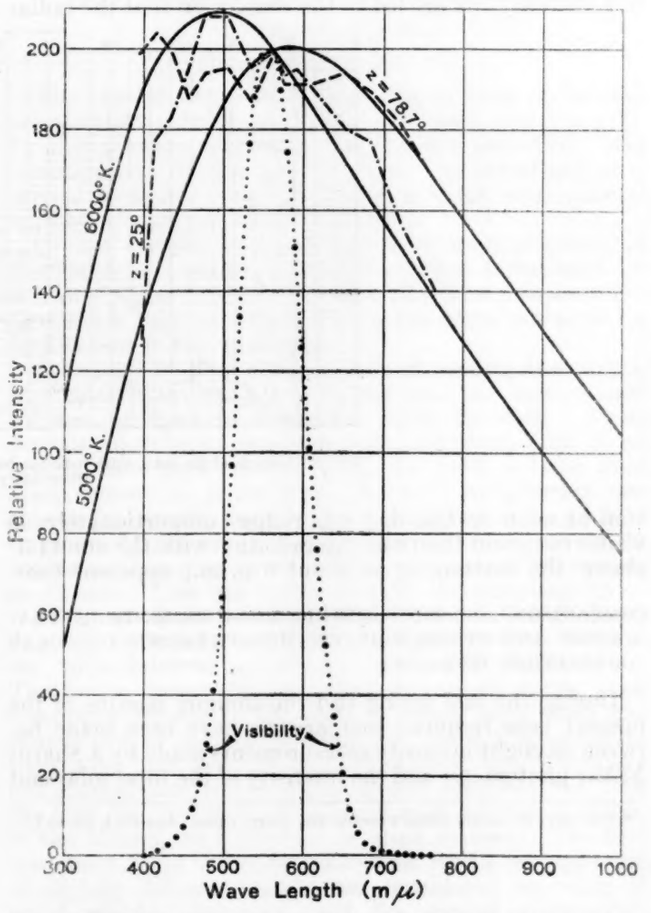

FIG. 3.—Energy distribution curves: According to Planck's equation, for temperatures of 5000° K and 6000° K, respectively; for the total solar and sky radiation with the sun at zenith distances, Z, of 25° and 78.7°, respectively, and for the relative visibility radiation

Planckian energy distribution to which they most nearly correspond. As we would expect, the correspondence is only approximate.

In Figure 3 are reproduced the Planckian energy distribution curves for temperatures of 5000° K and 6000° K,[20] and also the computed curves for the total solar and sky radiation on May 14, 1907, at Washington, for zenith distances of the sun of 25° and 78.7°, respectively. Comparing these two latter curves with the curve of relative visibility, we are led to the conclusion that the radiation at noon on this day was richer, proportionately, in visible radiation than was the radiation with the sun 11.3° above the horizon, or at about 6 p. m., apparent time.

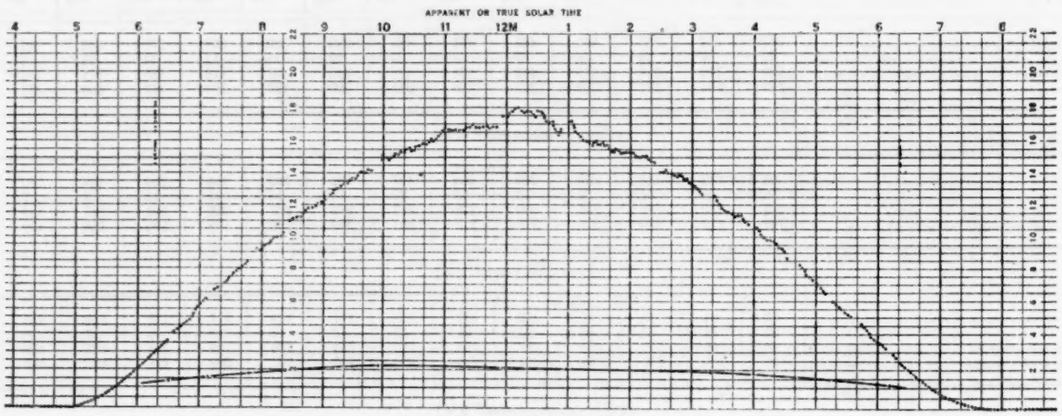

FIG. 4.—Record of the total solar radiation received on a horizontal surface at Washington, D. C., on July 11, 1924

COMPARISONS OF PHOTOMETRIC MEASUREMENTS OF DAYLIGHT AND PYRHELIOMETRIC MEASUREMENTS OF SOLAR RADIATION INTENSITY

During the late spring and the summer months of the present year frequent comparisons have been made between daylight intensity measurements made by a Sharp-Millar photometer and the intensity of the total solar and sky radiation as recorded by a thermoelectric pyrheliometer. The latter instrument was installed on the roof of the College of History Building, American University, D. C., and the photometer was read on the roof of the same building. The receiving surfaces of both instruments were exposed horizontally. Table 3 summarizes the comparisons between the readings of the two instruments. It also contains a summary of previous comparisons between solar radiation intensity at normal incidence and the corresponding illumination intensity.

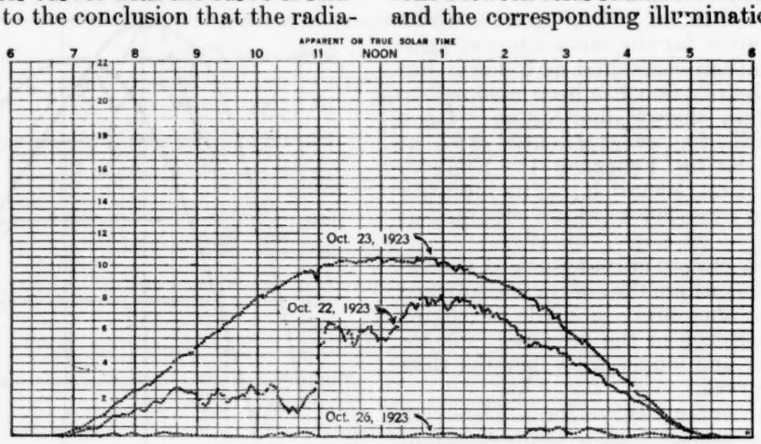

FIG. 5.—Records of the total solar radiation received on a horizontal surface at the University Observatory, Chicago, Ill.

Like Figure 3, Table 3 shows that the total radiation received on a horizontal surface is not quite so rich in luminous radiation with low sun as with high sun. This is also the case with direct solar radiation. In fact, when we consider the difficulties of obtaining accurate measurements of daylight illumination and the comparatively few measurements included in this research (about 10 for each air mass greater than 2.0, 26 for air mass 1.5, and 16 for air mass 1.1), we must conclude that the differences found between the illumination equivalent of direct solar radiation and the total radiation are of little significance, although the equivalent for the total radiation is consistently smaller, as we would expect.

[20] This curve fits closely Abbot's normal solar energy curve. (See fig. 1, Curve I.)

TABLE 3.—*Illumination equivalent of a gram-calory per minute per square centimeter of radiation with the sun at different zenith distances*

Air mass Solar zenith distance	1.1 25°	1.5 47.3°	2.0 60.0°	2.5 67.6°	3.0 70.7°	3.5 73.6°	4.0 75.7°	4.5 77.4°	5.0 78.7°
Direct solar radiation	F. C. 7020	F. C. 6880	F. C. 6740	F. C. 6650	F. C. 6580	F. C. 6520	F. C. 6460	F. C. 6410	F. C. 6370
Total radiation on a horizontal surface	7000	6740	6470	6320	6260	6220	6200	6200	6200

Figure 4 is a copy of the record made by the pyrheliometer on July 11, 1924. The upper trace is a record of the total (direct solar + diffuse sky) radiation received on a horizontal surface. The lower curve is drawn through records of sky radiation only, obtained by shading the pyrheliometer from direct sunlight. Vertical rows of dots were made on the record sheet at 6 a. m. and 6 p. m., apparent time, or about 6:13 a. m. and p. m., 75th meridian time. They show that the register clock was faster than apparent time, and gaining.

In figure 5 are reproduced three record traces made at the Weather Bureau Observatory, University of Chicago, in October, 1923. October 23 was a cloudless day, with a moderate northeast wind from off Lake Michigan, about a mile distant, which blew away the city smoke. October 22 was also a cloudness day, but with a light wind from the northwest in the morning. The station records state that "Dense city smoke prevailed until 10:30 a. m. (10:51 apparent time), when it was swept away by the wind shifting to the northeast. Standing objects not visible much in excess of one-eighth of a mile." Between 10 a. m. and 11 a. m., when the depression in the record is greatest, the radiation intensity averaged 24 per cent as great as during the same hour on the 23d.

On October 26, the observer's notes read: "Dense city smoke during forenoon. Sky overcast with clouds. Light rain after 2:43 p. m."

As we would expect, comparisons of individual series of photometric readings with the pyrheliometric record show large departures from the mean results given in Table 3. Thus, from the photometric readings made at about 7:48, 8:31, 9:51, and 11:48 a. m., July 11, 1924, we obtain for the ratio

$$\frac{\text{Illumination intensity (F. C.)}}{\text{Radiation intensity (gr.-cal./min.cm.}^2\text{)}}$$

the values 6320, 5920, 6400, and 7460, respectively; and at 10:08 a. m., 12:09 p. m., and 1:58 p. m., July 18, 1924, the ratios 7850, 6580, and 7140, respectively. It is believed that these variations are to be attributed principally to inaccuracies in the photometric readings rather than to inaccuracies in the pyrheliometric record. The sky was somewhat clearer on July 18 than on July 11.

A comparison between the illumination and the radiation intensities of sky light made at Washington, D. C., in summer, indicate that it is relatively richer in luminous radiation than is direct sunlight, and especially with low sun. This is hardly what we would expect from a comparison, in Figure 1, of Curve VII, for sky light, and Curves II, III, IV, and V, for sunlight, with Curve VI. It must be remembered, however, that a summer sky in Washington has a much lower color temperature, and, in consequence, radiates relatively less of the ultra-violet than is indicated by Curve VII. Therefore, the ratios as found may be correct; but in comparisons of skylight intensity we must take into account a large probable error in both the pyrheliometric and the photometer readings.

When dense clouds cover the sky so that the radiation intensity is perhaps even less than that from a clear sky the ratio of illumination intensity to radiation intensity is likewise abnormally high. The mean of 13 series of comparisons between illumination and radiation intensities with a completely overcast sky gives for the above ratio the value 7440.

Curve VII in Figure 1 indicates that for clear sky the ratio

$$\frac{\text{Illumination intensity}}{\text{Radiation intensity}}$$

should be lower than for direct solar radiation. Priest's color temperatures of sky light, already referred to, give a like indication, although with cloudy skies the difference is small.

CONCLUSIONS

With cloudless skies the illumination equivalents of Table 3 when applied to radiation intensities should give daylight intensities with an accuracy comparable to that of ordinary photometric readings. The factor 6700 will, on an average, give the daylight intensity within ± 5 per cent, giving too low intensities near noon in summer and too high intensities when the sun is near the horizon.

With the sky covered with clouds the factor averages higher, probably not far from 7,000.

APPLICATION OF SCHUSTER'S PERIODOGRAM TO LONG RAINFALL RECORDS, BEGINNING 1748

By DINSMORE ALTER

(University of Kansas, Nov., 1924)

The present paper is an extension of work on rainfall periodicities carried on during the past four years(**1**). In the previous papers a single short periodicity was investigated. In the present paper the investigation is carried to longer periods to which a much more general method of analysis must be applied.

Of the various methods that have been proposed in the search for hidden periodicities, that formulated by Schuster (**2**) and used by him in a search for periods in the Greenwich magnetic data, seems the most practical for application to this problem.

Schuster's method consists, first, of passing sine curves, of arbitrarily selected periods, through the data in such manner as best to represent them by each. These periods must be so closely chosen that there shall be no intermediate ones untried that can have a large final disagreement in phase from the next neighboring one chosen for examination. The second part of the method consists of plotting the intensities of these curves as ordinates of another curve whose abscissae are the periods so chosen. This last curve he calls the periodogram.

The method of obtaining these sine curves is as follows: Suppose a period to be tried of length equal to n times the time interval α between successive observations. The first n data values are then written as a row, each heading a column. The next n values then form the second row of these n columns, etc, until all p observations have been used or, as is often done, until there are not enough data left to form another complete row. In the first case the average value of each column is taken, in the second the sum may be used instead. The first case has a slight theoretical disadvantage in that columns of slightly different weight are considered as being of equal weight. Schuster used the second alternative, although it involves the neglect of considerable data

when long periods are being investigated. In this paper the column averages are used.

Let any one of the sums of the n columns be ϕ_m. Schuster defines

$$A = \Sigma\, \phi_m \cos \frac{2\pi_m}{t} \quad B = \Sigma\, \phi_m \sin \frac{2\pi_m}{t}$$

$$S = (A^2 + B^2)\, \frac{\alpha}{p}$$

If we define averages instead of sums, as ϕ_m we must then define

$$I = \frac{A^2 + B^2}{\eta^2 \alpha^2}$$

since S determined by the former equation would increase as the square of the period examined.

He defines as h the ratio between I of any period and the mean value of I. The probability, then, of obtaining a given value of h, or larger, by accident is $1/\epsilon^h$. About one computed value of h out of a thousand should be as large as seven by mere accident, and about one out of a million as large as 14.

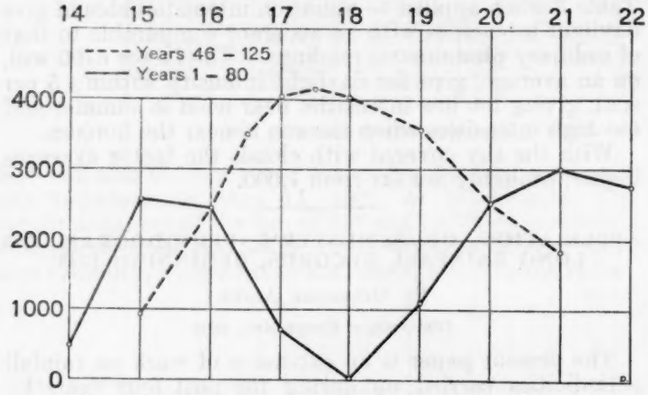

FIG. 1.—Periodogram from years 1–80 and 46–125 of fictitious data

Although Schuster has brought out analytically the limitations of the periodogram in resolving power, these are larger than is often recognized and it may be well to show them by a numerical example. For this purpose values of fictitious data have been computed from two sine curves, at phase zero, together at the year 1, of equal amplitudes and of periods 16 and 20 years—a case much simpler than will be met in actual investigations and, therefore, giving a smaller range of uncertainty to deductions from the periodogram. The irregular curve obtained by adding these components repeats itself every 80 years. Periodograms have been computed from two 80-year intervals; i. e., from years 1–80 and 46–125. The data are given in Table 1 and the periodograms in Table 2 and Figure 1. Exactly the same shape of curve has given each of these periodograms. The data have merely begun in one place for one and in another place for the other. Since the ordinates of these periodograms for periods below 15 and above 22 are very small, rapidly approaching zero, the values of h at the peaks are very large and would, on our criterion of probabilities, indicate true periods. Yet one periodogram tells us that there is but one period of about 17½ years, the other that there are two, of 15½ and 21 years, these despite the fact that in this case we know that there are two of 16 and of 20 years. *However, the periodogram has value even in these cases for it tells us that there are one or more true periodicities in this general region, even though it can not locate them accurately.* Evidently no period of length $n\alpha$ making p/n cycles in the data can be located more certainly than within a range r such that $r > \frac{n^2\,\alpha}{p-n}$. How much greater r must be than this value will depend upon the complexity of the data and the importance of accidental or other nonperiodic factors. For example, even if the sun-spot data were the combination of two fairly short constant periodicities, without other factors entering, the 173 years' data available would not locate the true length of the 11-year period within about two-thirds of a year. No matter how sharply the periodogram seems to locate a period, we must at all times allow this range, a greater uncertainty than some investigators seem to have realized.

The first part of this investigation consisted of a search for and combination of the longest rainfall records available in various parts of the world. As in the preceding papers, an attempt was made to use all long records that are from stations where the rainfall is either purely marine or purely continental and to avoid such places as the central part of the United States, where it is mixed, with no great preponderance of the one type over the other. Before combining different stations each year's data have been reduced to the percentage of normal which fell in that year, in order that the omission of years from some one station may not give a record lacking too much in homogeneity to be useful. Such lack of data is an unavoidable defect in the compilations of data by the weather bureaus of the United States and of other countries. In the case of monthly data there is the additional necessity of eliminating the seasonal variation. Usable records were found in northern Europe, eastern United States, California and Oregon, and in India. From the Indian data that of the Punjab, which is almost purely continental, was chosen. These records form Tables 3–6 and Figures 2–5.

In northern Europe it has been possible to compile a record of 173 years, during the great majority of which time three or more scattered stations are available. It is recognized that the weights of the early records are less than those of the later ones both because of the fewer stations available and also because, presumably, more care has been exercised recently. However, when one considers the question of adjusting weights he sees that any arbitrary scheme is open to objections. It has, therefore, seemed best here to make a solution considering all years as of equal weight. The periodogram from these data should locate fairly accurately periods of less than 10 to 15 years and tell us something about longer periods shorter than 40 years.

In the eastern United States there are available 17 station records, extending back at least to 1840, which have been sent to me by Professor Talman, of the United States Weather Bureau. I have not found any long New England records. These, reduced to percentages of normal, are given as Table 4 and as Figure 3, with their mean in the last column of the table. The mean forms a very valuable record of 103 years, second in weight only to that of northern Europe.

Mr. Beals and Mr. Wells, State section directors of California and of Oregon, respectively, have sent me eight long records, of which the percentages of normal form Table 5 and Figure 4. These give a 73-year record from which to form a periodogram.

In the Punjab a 56-year record, given as Table 6 and Figure 5, has been used.

Although not used in this paper and, therefore, omitted from the tables, the author has the monthly values of rainfall for each station used. Some of these can be found in the tables of the earlier paper mentioned above.

This search falls naturally into four parts, of which this paper presents the first:

(*a*) *Periodicities greater than eight years.*—For such periods yearly values of data are sufficient and the approximate and rather rapid method of calculation wherein a value is averaged or repeated in order to obtain non-integral periods is entirely satisfactory.

(*b*) *Periodicities between approximately four and eight years.*—Yearly values of data are still satisfactory, but in forming the tables for the computation of I the approximation involved in repeating or averaging a year can not be used. The tabulation of data in a column assumes that all the values are in the same phase. There will, however, when the device described above is used, often be half a phase departure from the proper place. If eight places are computed for the cycle, data will sometimes be displaced as much as 22.5°. This begins to count and for such periods it is necessary to compute accurately the phase of each datum value. This increases the work very much.

(*c*) *Periodicities between two and four years.*—At about four years the change in phase during a year makes it necessary to use data given at more frequent intervals. For this range quarterly values will suffice.

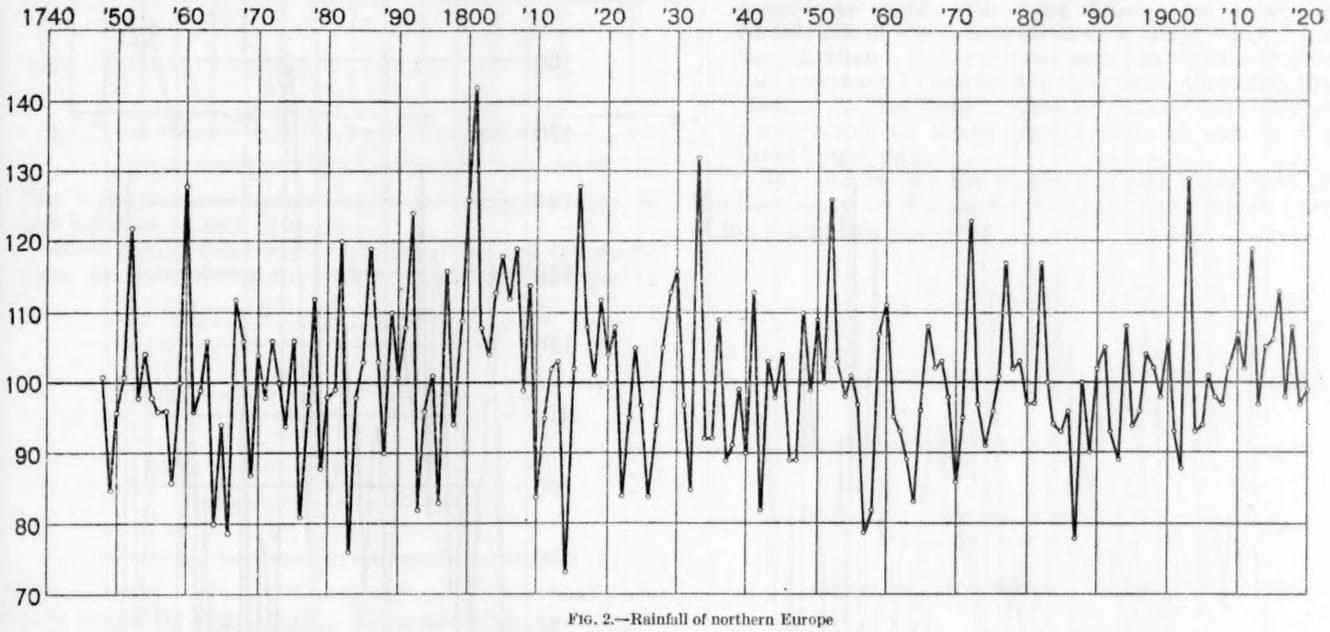

FIG. 2.—Rainfall of northern Europe

(*d*) *Periodicities between one and two years.*—Monthly values of data should be used.

The periodogram of northern Europe has, of course, a much greater weight than that from any other region. Short periods can be determined with greater accuracy, while longer periods can be determined than is the case with the shorter records. Three features are seen to stand out in this periodogram, which is shown as Table 7 and Figure 6. First in importance is the very low intensity between 10½ and 14 years; second is the very high intensity from 15 to 16 years; and third, the moderately high intensity near 10 years. The peak near 15 years with $h=5.83$ is high enough to suggest that even without corroboration from other sections we may begin to consider the possibility of its existence as due to other than fortuitous causes. If it be real, its true length may, as

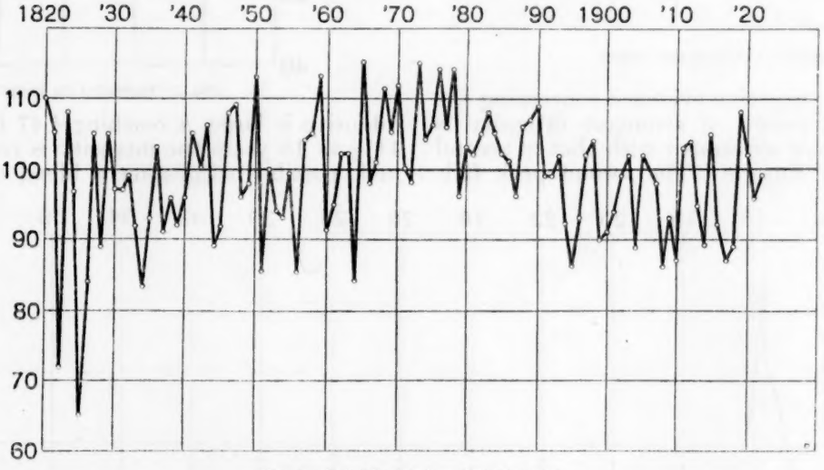

FIG. 3.—Rainfall of eastern United States

seen above, due to the limitation of the method, be anywhere between 14 and 18 years.

The periodogram of the eastern United States, shown as Table 8 and Figure 7, stands next in weight. Here

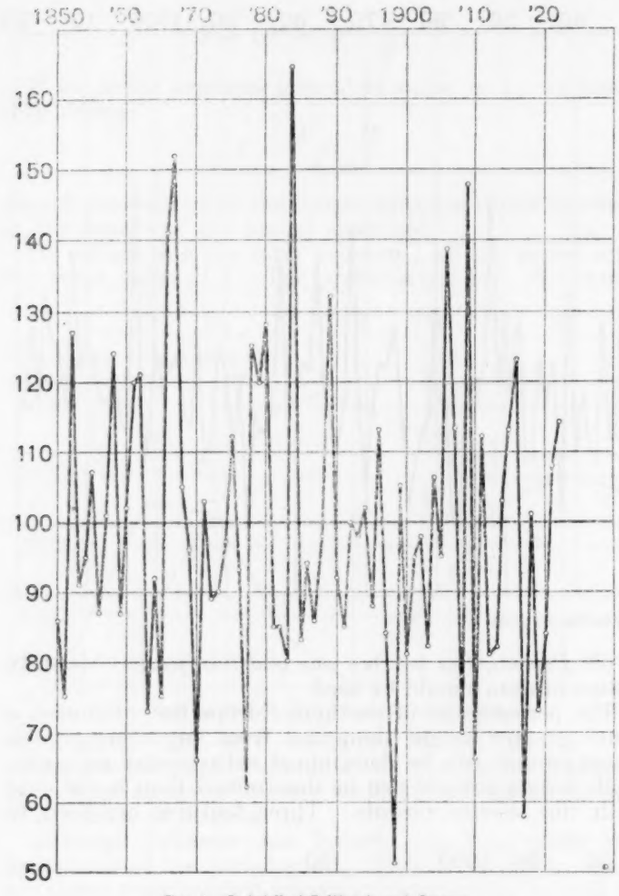

FIG. 4.—Rainfall of California and Oregon

again, we find entirely negative evidence concerning the 11-year period. The period of strongest intensity is found to be in very close agreement with that of second intensity for northern Europe. The second peak falls

9 and Figure 8. A third time we find that the 11-year period fails to appear, although the intensity rises above normal very soon thereafter. From 9 to 10 years the

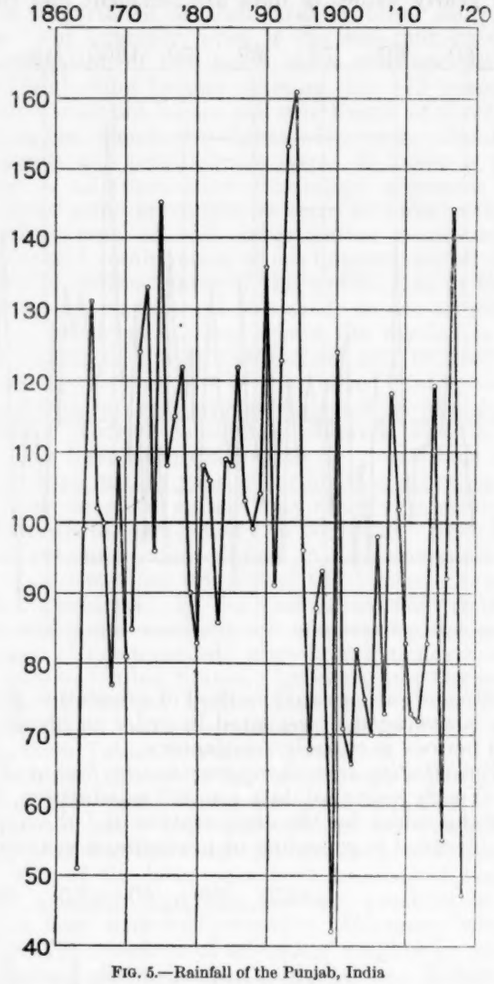

FIG. 5.—Rainfall of the Punjab, India

intensity is large, h reaching 4.47 for 9⅓ years. From 11½ to 15 years the intensity is continually above normal, possibly suggesting a blend of two periods as in

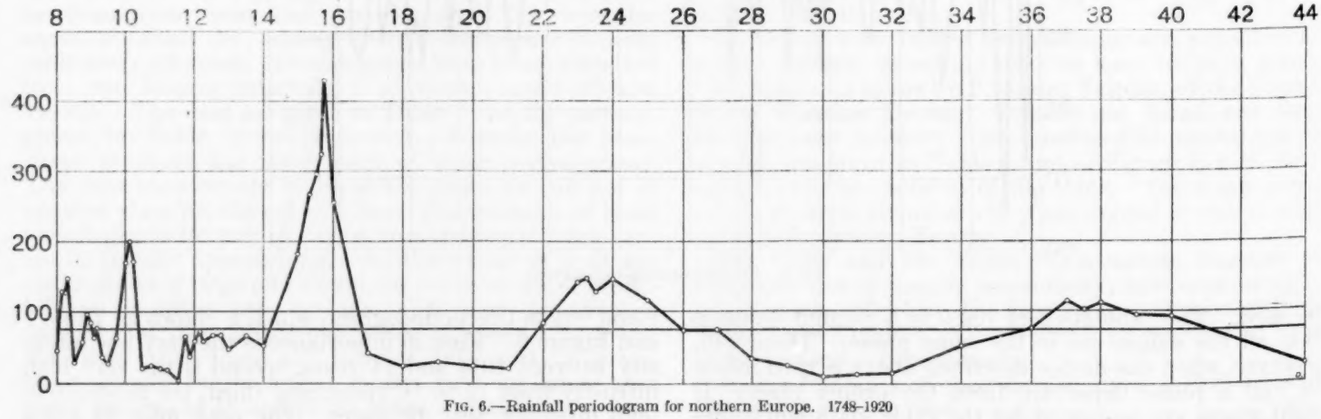

FIG. 6.—Rainfall periodogram for northern Europe. 1748–1920

at 14½ years with a range of fully two years in uncertainty, overlapping the primary peak of the northern European data.

The periodogram of next weight is that from the 73-years' data of the Pacific coast. This is shown as Table

Figure 2. It also rises very slightly above normal once more at 15⅔ years..

The data of least weight are those from the Punjab, shown as Table 10 and Figure 9, where only 56 years are available. This periodogram agrees very closely with

the much longer record from northern Europe, except that it is impossible from such a short record to obtain large values of h. The 11-year period is entirely absent.

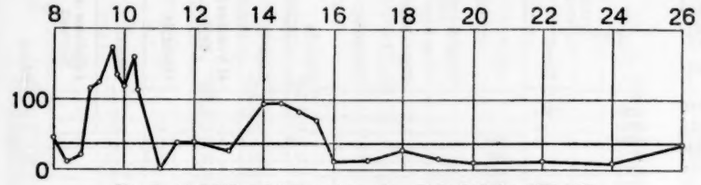

FIG. 7.—Rainfall periodogram for eastern United States, 1820–1922

The highest intensities are found in the regions near 10 and between 14 and 17 years.

These results from widely separated parts of the world seem to show definitely that a simple 11-year period

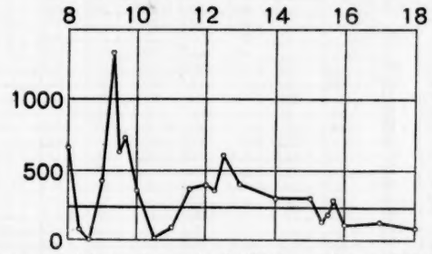

FIG. 8.—Rainfall periodogram for California and Oregon, 1850–1922

does not exist. However, some such period practically has been proved by Douglass (3). The conclusion, then, must be that Douglass's period is either a complex mean from longer and shorter periodicities or else a variable cycle.[1]

Nothing more is definitely shown here. It is probable that one or more periods exist in the neighborhood of 10 years. The same is true of the region between 13 and 16 years. If they do, whether they be exact periods or variable cycles can not be shown here. It may be possible to speak with more definiteness after the completion of the second division of the problem. On the otherhand, it may require many more data to give full assurance as to which is the case. Certainly the chance of knowing definitely about the shorter periods will be much greater than it can be for these longer ones.

My thanks are due to the research committee of the University of Kansas for a grant under which part of the computing was done.

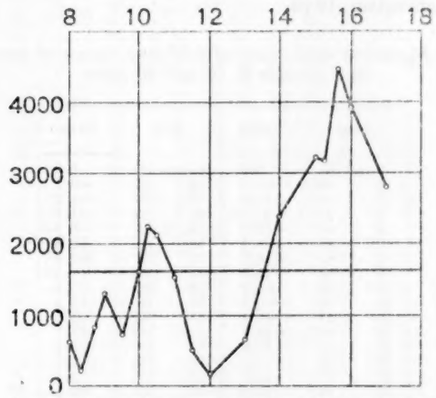

FIG. 9.—Rainfall periodogram for the Punjab, India, 1863–1918

[1] The point may well be emphasized that experience has shown it to be much more difficult to discern periodicities on the basis of precipitation data than on the basis of temperature data.

That the 11-year cycle is variable, and systematically so, is a principal thesis of a paper by H. W. Clough, of the United States Weather Bureau, entitled: "A systematically varying period with an average length of 28 months in weather and solar phenomena." See MO. WEATHER REV., September, 1924. Reprints of this paper are available.

Of the greatest significance also, in this connection, is the paper by A. A. Michelson, "Determination of periodicities by the harmonic analyzer with an application to the sun-spot cycle," in Astrophys. Jour., 38, 1913, pp. 268–274. On p. 273: "It will probably be found that even the 11-year period is in fact not constant, but is subject to secular change; * * *."—B. M. V.

BIBLIOGRAPHY

1. **Alter, Dinsmore:** A possible rainfall period equal to one-ninth the sun-spot period. MONTHLY WEATHER REVIEW, February, 1921.

Continuation of investigation of a possible rainfall period and application of Marvin's periodocrite to rainfall periodicity. Kansas University Science Bulletin, Vol. XIII, Nos. 8 and 9.

A rainfall period equal to one-ninth the sun-spot period. Kansas University Science Bulletin, Vol. XIII, No. 11.

2. **Schuster, Arthur:** The periodogram of magnetic declination as obtained from the records of the Greenwich Observatory during the years 1871–1895. Cambridge Phil. Soc. Trans., Vol. XVIII, page 107 (1899).

The periodogram and its optical analogy.

On sun-spot periodicities—Preliminary note. Roy. Soc. Proc. A, Vol. LXXVII, pages 136–140 and 141–146.

On the periodicities of sun spots. Phil. Trans. Roy. Soc., Vol. A, CCVI, pages 69–100.

3. **Douglas, A. E.:** Climatic cycles and tree growth. Carnegie Inst. of Washington, 1919.

TABLE 1.—*Fictitious data, sum of two sine curves of amplitude 10 and periods of 16 and 20 years*

Year	Value	Year	Value
1 and 81	0.0	41 and 121	0.0
2 82	+6.9	42 122	−0.7
3 83	+13.0	43 123	−1.2
4 84	+17.3	44 124	−1.1
5 85	+19.5	45 125	−0.5
6 86	+19.2	46 126	+0.8
7 87	+16.6	47 127	+2.4
8 88	+11.9	48 128	+4.3
9 89	+5.9	49 129	+5.9
10 90	−0.7	50 130	+6.9
11 91	−7.1	51 131	+7.1
12 92	−12.3	52 132	+6.1
13 93	−15.9	53 133	+4.1
14 94	−17.3	54 134	+1.1
15 95	−16.6	55 135	−2.4
16 96	−13.8	56 136	−6.2
17 97	−9.5	57 137	−9.5
18 98	−4.3	58 138	−11.9
19 99	+1.2	59 139	−13.0
20 100	+6.1	60 140	−12.3
21 101	+10.0	61 141	−10.0
22 102	+12.3	62 142	−6.1
23 103	+13.0	63 143	−1.2
24 104	+11.9	64 144	+4.3
25 105	+9.5	65 145	+9.5
26 106	+6.2	66 146	+13.8
27 107	+2.4	67 147	+16.6
28 108	−1.1	68 148	+17.3
29 109	−4.1	69 149	+15.9
30 110	−6.1	70 150	+12.3
31 111	−7.1	71 151	+7.1
32 112	−6.9	72 152	+0.7
33 113	−5.9	73 153	−5.9
34 114	−4.3	74 154	−11.9
35 115	−2.4	75 155	−16.6
36 116	−0.8	76 156	−19.2
37 117	+0.5	77 157	−19.5
38 118	+1.1	78 158	−17.3
39 119	+1.2	79 159	−13.0
40 120	+0.7	80 160	−6.9

TABLE 2.—*Fictitious data of periods 16 and 20 years*

PERIODOGRAM FROM YEARS 1–80

Period in years	Intensity	A	B
14	479	−235	−197
15	2542	−652	+384
16	2455	0	+792
17	737	+367	+280
18	14	−67	+12
19	1071	+385	+489
20	2520	0	+1004
21	3018	+641	+959
22	2740	+1043	+485

PERIODOGRAM FROM YEARS 46–125

15	921	−372	−251
16	2480	−736	+304
16½	3500	−571	−828
17	4030	+389	+1005
17½	4157	−172	+1083
18	4040	+397	+1072
19	3590	+970	+593
20	2520	+1004	0
21	1810	+768	−456

TABLE 3.[1]—*Percentages of rainfall in northern Europe*

[See Table 11]

Year	Lund [2]	Abo [3]	Montdidier	Copenhagen [4]	Chilgrove	Utrecht	London	Haverford west	Glengyle	Belfast	4 stations in Norway	Mean
1748	(101)											101
1749	85											85
1750	91	100										96
1751		101										101
1752		122										218
1753	96	101										92
1754	89	119										104
1755	71	124										98
1756	75	117										96
1757	93	99										96
1758	81	92										86
1759	77	122										100
1760	119	138										128
1761	107	84										96
1762	107	91										99
1763	103	108										106
1764	80											80
1765	93	94										94
1766	82	76										79
1767	116	107										112
1768	105	108										106
1769	100	74										87
1770	110	97										104
1771	104	92										98
1772	117	96										106
1773	99	101										100
1774	111	76										94
1775	114	98										106
1776	89	73										81
1777	97	97										97
1778	101	123										112
1779	103	74										88
1780	103	93										98
1781	108	90										99
1782	131	109										120
1783	85	66										76
1784	97	101	96									98
1785	119	95	96									103
1786	131	115	110									119
1787	100	95	113									103
1788	94	83	92									90
1789	110	99	120									110
1790	113	94	96									101
1791	93	112	104									108
1792	130	126	116									124
1793	85	90	72									82
1794	91	114	83									96
1795	101	113	90									101
1796	98	70	81									83
1797	127	139	82									116
1798	122	88	71									94
1799	116		102									109
1800	134		117									126
1801	147		138									142
1802	122		94									108
1803	116	81	115									104
1804	(115)	101	124									113
1805	(128)	104	121									118
1806		103	120									112
1807	121	114	123									119
1808	119	88	90									99
1809	127	95	120									114
1810	78	74	99									84
1811	96	71	117									95
1812	78	98	131									102
1813	95	101	113									103
1814	61	74	85									73
1815	108	87	112									102
1816	109	128	146									128
1817	100	103	120									108
1818	103	87	113									101
1819	98	115	123									112
1820	103	100	110									104
1821	(111)	116	115	89								108
1822	87	65	98	84								84
1823	(97)	81	90	113								95
1824	106	89	106	118								105
1825	98	86	74	131								97
1826	64	68	85	88								84
1827	83	76	100	117								94
1828	101	92	110	118								105
1829	110	114	111	118								113
1830	(120)	117	98	127								116
1831	(117)	69	100	101								97
1832	(98)	90	80	71								85
1833	(120)	208	68	131								132
1834	98	95	80	90	96							92
1835	84		105	88	90							92
1836	93	78	118	119	119							109
1837	86		111	81	79							89
1838	84		99	92	89							91

[1] For data on lengths of periods, sources, etc., used in Tables 3, 4, and 5, see Table 11, following.

[2] From 1861–1910 mean value from Swedish towns is used.

[3] Beginning with 1803 Warsaw is substituted.

[4] Beginning with 1861 the mean of Danish towns is substituted.

TABLE 3.—*Percentages of rainfall in northern Europe*—Continued

Year	Lund	Abo	Montdidier	Copenhagen	Chilgrove	Utrecht	London	Haverford west	Glengyle	Belfast	4 stations in Norway	Mean
1839	77	----	120	82	118	----	----	----	----	----	----	99
1840	91	----	99	88	84	----	----	----	----	----	----	90
1841	140	71	99	127	127	----	----	----	----	----	----	113
1842	(78)	79	86	70	87	----	----	----	----	----	----	82
1843	95	91	107	121	101	----	----	----	----	----	----	103
1844	77	121	94	115	82	----	----	----	----	----	----	98
1845	113	89	104	123	90	----	----	----	----	----	----	104
1846	81	71	98	92	101	----	----	----	----	----	----	89
1847	73	98	114	86	76	----	----	----	----	----	----	89
1848	118	94	98	108	131	----	----	----	----	----	----	110
1849	99	107	95	106	96	93	----	----	----	----	----	99
1850	85	154	106	102	94	114	----	----	----	----	----	109
1851	92	149	82	102	76	96	----	----	----	----	----	100
1852	146	84	122	119	148	135	----	----	----	----	----	126
1853	75	136	100	86	111	108	----	----	----	----	----	103
1854	90	127	111	98	64	96	----	----	----	----	----	98
1855	96	147	87	90	84	100	----	----	----	----	----	101
1856	81	94	104	102	96	106	----	----	----	----	----	97
1857	70	101	79	65	91	67	----	----	----	----	----	79
1858	68	121	79	71	76	80	----	----	----	----	----	82
1859	113	129	106	107	100	95	----	----	----	----	----	107
1860	121	106	104	102	122	98	126	119	103	111	----	111
1861	94	90	76	103	84	92	87	108	122	98	----	95
1862	99	67	79	99	94	76	108	80	114	113	----	93
1863	94	77	63	98	89	71	84	94	115	107	----	89
1864	88	107	75	91	72	71	66	83	88	85	----	83
1865	76	119	97	70	112	97	115	106	79	93	----	96
1866	116	81	97	122	107	102	124	114	110	103	----	108
1867	113	97	93	117	86	96	103	116	108	95	96	102
1868	102	130	88	106	105	74	91	117	129	91	104	103
1869	97	109	83	93	97	113	99	114	99	94	83	98
1870	99	113	82	81	80	94	83	83	77	87	70	86
1871	85	119	100	84	97	96	98	97	98	92	76	95
1872	131	103	109	124	126	112	132	145	139	129	106	123
1873	109	101	87	105	91	92	89	95	104	90	102	97
1874	81	78	80	90	85	90	74	106	116	101	101	91
1875	78	99	89	90	103	110	111	122	99	93	67	96
1876	106	101	107	100	103	92	102	111	102	116	72	101
1877	108	86	121	119	131	112	110	134	140	122	106	117
1878	102	96	124	106	97	103	133	113	89	84	77	102
1879	97	101	110	102	108	98	132	103	95	97	88	103
1880	105	93	102	112	109	95	118	85	75	83	89	97
1881	109	75	100	90	99	108	109	94	87	111	90	97
1882	116	113	125	118	104	133	106	132	114	114	115	117
1883	102	----	110	93	96	89	95	106	110	98	103	100
1884	100	----	93	99	77	82	80	91	117	96	100	94
1885	41	----	102	93	98	96	104	105	492	86	115	93
1886	34	----	104	87	111	88	106	120	88	107	114	96
1887	84	----	63	80	74	69	75	73	73	68	119	78
1888	97	----	94	108	103	97	109	98	97	95	107	100
1889	91	----	92	84	87	114	93	77	83	90	87	90
1890	144	----	99	97	85	117	83	89	104	94	109	102
1891	100	----	----	110	121	92	110	106	103	92	113	105
1892	93	----	----	92	81	110	88	78	98	90	109	93
1893	102	----	----	94	79	98	77	74	100	75	100	89
1894	109	----	----	100	126	128	109	104	111	91	98	108
1895	107	----	----	99	103	100	84	81	81	96	96	94
1896	108	----	----	92	105	99	92	85	83	95	106	96
1897	110	----	----	108	109	97	89	106	105	103	109	104
1898	128	----	----	120	83	102	69	88	122	88	119	102
1899	107	----	----	92	87	97	88	88	116	101	102	98
1900	112	----	----	112	113	96	91	104	113	117	100	106
1901	84	----	----	95	90	110	87	95	83	93	102	93
1902	91	----	----	91	99	92	81	84	72	88	98	88
1903	113	----	----	115	145	132	149	118	141	123	125	129
1904	105	----	----	96	107	78	81	89	97	92	96	93
1905	89	----	----	102	89	110	90	83	84	92	108	94
1906	103	----	----	98	114	94	95	105	89	104	111	101
1907	104	----	----	94	105	89	90	92	93	110	104	98
1908	96	----	----	97	93	95	92	93	96	112	100	97
1909	115	----	----	105	113	103	105	85	82	107	106	102
1910	120	----	----	114	105	116	99	95	97	117	104	107
1911	----	----	----	109	106	89	97	104	103	103	106	102
1912	----	----	----	118	119	138	109	118	116	129	108	119
1913	----	----	----	92	104	98	88	111	91	109	86	97
1914	----	----	----	103	115	108	101	105	104	101	106	105
1915	----	----	----	96	130	122	126	103	82	106	81	106
1916	----	----	----	123	106	123	133	91	105	109	----	113
1917	----	----	----	96	93	107	117	87	83	104	----	98
1918	----	----	----	98	98	121	116	109	105	110	----	108
1919	----	----	----	97	112	101	102	89	79	100	----	97
1920	----	----	----	110	----	88	----	----	----	----	----	99

TABLE 4.—*Percentages of rainfall in eastern United States*

Year	Charleston, S. C.	Washington, D. C.	Nashville, Tenn.	Savannah, Ga.	Philadelphia, Pa.	Pittsburgh, Pa.	Rochester, N. Y.	Albany, N. Y.	New York City, N. Y.	Penn Yan, N. Y.	Baltimore, Md.	St. Paul, Minn.	New Orleans, La.	St. Louis, Mo.	Lebanon, Pa.	Cincinnati, Ohio	Portsmouth, Ohio	Mean
1817	----	----	----	----	----	----	----	----	----	----	121	----	----	----	----	----	----	121
1818	----	----	----	----	----	----	----	----	----	----	81	----	----	----	----	----	----	81
1819	----	----	----	----	----	----	----	----	----	----	72	----	----	----	----	----	----	72
1820	----	----	----	----	115	----	----	----	----	----	106	----	----	----	----	----	----	110
1821	----	----	----	----	85	----	----	----	----	----	125	----	----	----	----	----	----	105
1922	----	----	----	----	72	----	----	----	----	----	73	----	----	----	----	----	----	72
1823	----	----	----	----	104	----	----	----	----	----	111	----	----	----	----	----	----	108
1824	----	71	----	----	116	----	----	----	----	----	105	----	----	----	----	----	----	97
1825	----	60	----	----	69	----	----	----	----	----	65	----	----	----	----	----	----	65
1826	----	46	----	----	82	----	----	86	131	----	76	----	----	----	----	----	----	84
1827	----	----	----	----	90	----	----	130	118	----	81	----	----	----	----	----	----	105
1828	----	58	----	----	91	----	----	98	115	----	82	----	----	----	----	----	----	89
1829	----	106	----	----	98	----	90	99	108	112	130	----	----	----	100	----	----	105
1830	----	----	----	----	105	----	102	109	102	104	97	----	----	----	98	----	59	97
1831	----	----	----	----	102	----	104	103	92	103	93	----	----	90	93	----	96	97
1832	95	----	----	----	93	----	94	116	93	106	85	----	----	----	84	----	111	99
1833	100	----	----	----	114	----	91	109	89	90	102	----	----	----	101	----	86	92
1834	141	----	----	----	80	----	51	85	80	77	73	----	----	----	79	----	83	83
1835	101	----	----	----	92	----	86	105	68	92	85	----	----	----	85	128	84	93
1836	84	116	----	----	100	----	84	116	86	96	136	----	92	----	90	141	99	103
1837	116	78	----	71	92	99	92	107	76	85	112	87	----	67	79	105	121	91
1838	121	----	----	----	106	----	76	110	80	103	117	100	----	70	81	97	94	96
1839	109	94	----	----	102	70	90	99	79	108	128	76	81	118	85	75	62	92
1840	95	----	124	94	111	79	88	115	84	102	93	83	78	103	65	116	103	96
1841	111	111	129	139	130	96	97	99	105	83	109	78	87	106	88	101	117	105
1842	87	----	112	127	114	112	100	120	98	105	87	95	77	80	90	101	103	100
1843	113	----	122	87	109	107	94	126	84	101	121	86	108	86	100	126	127	106
1844	75	----	88	97	94	90	78	91	94	69	81	109	86	114	73	106	84	89
1845	96	----	145	75	94	88	103	103	80	84	71	91	95	94	75	113	96	92
1846	91	102	----	113	103	132	111	104	85	100	116	94	118	113	107	132	110	108
1847	98	88	----	139	106	128	108	107	105	96	82	79	94	131	109	160	117	109
1848	89	57	----	113	82	95	96	126	77	78	86	83	94	162	75	124	100	96
1849	63	----	----	100	99	96	99	96	71	79	76	178	92	114	79	130	105	98
1850	49	----	----	110	128	104	115	135	105	109	111	92	90	126	145	134	139	113
1851	68	----	----	88	83	82	75	90	92	93	95	84	88	106	80	78	75	85
1852	103	99	----	109	107	114	105	84	83	----	128	54	77	116	99	133	96	100
1853	89	82	----	94	95	93	98	119	109	102	90	74	108	77	97	101	70	94
1854	78	77	----	86	94	74	88	89	103	68	147	96	93	101	85	125	76	93
1855	72	73	----	77	103	120	102	110	102	103	73	89	73	125	121	121	118	99
1856	101	83	----	90	79	74	86	102	83	75	57	82	118	105	71	63	----	85
1857	79	101	----	67	113	108	136	119	91	153	95	115	84	97	114	87	----	104
1858	99	97	----	106	93	100	108	89	87	92	115	99	106	171	98	121	----	105
1859	103	103	----	----	138	99	98	84	141	100	138	107	87	153	121	111	113	113
1860	91	92	----	----	103	99	89	84	73	89	93	125	69	74	109	86	82	91
1861	91	107	----	----	108	----	107	94	88	113	108	112	----	95	102	106	102	95
1862	107	96	----	----	105	81	116	99	110	109	88	123	----	110	87	94	97	102
1863	68	111	----	----	115	88	91	113	102	139	106	57	----	101	128	98	90	102
1864	118	89	----	----	108	----	122	73	93	110	57	53	----	94	87	82	87	84
1865	118	120	----	----	132	140	106	95	106	109	83	137	----	117	105	108	131	115
1866	75	118	----	----	106	----	107	89	90	93	68	100	----	104	89	122	109	98
1867	126	142	----	----	143	----	92	99	126	----	82	121	----	94	109	74	110	101
1868	126	115	----	----	120	----	118	109	135	----	81	110	----	113	84	111	110	111
1869	89	107	----	----	114	----	121	115	114	----	68	116	----	117	98	96	102	105
1870	99	89	----	----	103	----	119	145	109	119	56	110	85	73	92	77	99	112
1871	130	93	69	123	111	----	109	148	115	----	82	110	113	58	93	74	75	100
1872	117	76	84	127	113	88	109	102	108	----	88	107	106	76	----	85	76	98
1873	128	112	108	97	129	115	149	103	94	----	123	124	115	113	----	101	112	115
1874	129	85	122	114	108	109	107	99	94	103	84	128	106	94	----	92	93	104
1875	105	101	112	98	94	94	90	100	107	93	113	110	150	107	----	105	111	106
1876	161	117	98	129	111	102	108	100	111	117	116	85	118	120	----	129	109	114
1877	160	129	104	119	87	96	102	94	97	107	107	104	111	103	----	85	85	106
1878	159	147	102	105	81	107	146	128	110	143	125	82	116	102	----	102	73	114
1879	103	80	120	92	86	97	106	101	86	86	90	118	90	64	----	127	87	96
1880	96	95	141	100	79	89	125	85	88	83	104	107	122	86	----	134	119	103
1881	89	103	101	76	71	103	115	95	95	105	122	141	112	93	----	116	99	102
1882	117	114	132	94	107	107	75	88	110	81	105	83	88	107	----	128	137	105
1883	105	112	122	97	92	120	----	102	92	117	101	96	122	100	107	128	118	108
1884	124	122	113	101	92	97	94	101	131	92	114	94	105	101	110	96	103	105
1885	139	109	90	146	78	95	85	90	99	104	115	91	112	114	100	83	91	102
1886	74	142	94	85	87	108	111	89	110	109	130	82	96	110	98	77	110	101
1887	92	86	101	89	99	116	61	103	110	91	109	93	113	88	----	86	101	95
1888	102	111	105	94	103	110	83	116	125	104	109	93	146	103	103	86	117	106
1889	107	150	88	95	119	115	107	103	138	----	155	61	85	83	128	76	96	107
1890	98	102	125	95	80	140	130	117	123	----	117	84	74	94	113	117	140	109
1891	94	129	110	89	89	106	101	109	98	----	135	78	68	76	106	95	104	99
1892	110	103	105	85	81	90	105	91	92	----	112	117	100	104	98	78	107	99
1893	146	90	97	123	88	105	107	92	125	----	80	93	84	98	103	108	92	102
1894	117	76	88	105	94	78	105	92	104	----	95	93	95	68	115	63	88	92
1895	114	84	90	109	73	76	91	78	84	----	100	87	99	78	69	72	76	86
1896	98	76	84	88	75	123	110	73	90	----	96	125	87	91	97	85	97	93

TABLE 4.—*Percentage of rainfall in eastern United States*—Con.

Year	Charleston, S. C.	Washington, D. C.	Nashville, Tenn.	Savannah, Ga.	Philadelphia, Pa.	Pittsburgh, Pa.	Rochester, N. Y.	Albany, N. Y.	New York City, N. Y.	Penn Yan, N. Y.	Baltimore, Md.	St. Paul, Minn.	New Orleans, La.	St. Louis, Mo.	Lebanon, Pa.	Cincinnati, Ohio	Portsmouth, Ohio	Mean
1897	104	108	92	108	99	97	90	106	104	----	118	110	76	100	101	107	120	102
1898	96	92	105	120	115	99	113	101	107	109	91	91	86	122	114	96	117	104
1899	91	108	93	84	94	94	80	75	100	89	101	99	54	86	95	85	104	90
1900	79	101	102	90	96	71	114	80	98	105	79	123	99	74	84	68	84	91
1901	67	102	80	74	107	113	112	106	111	122	107	93	101	62	104	44	96	94
1902	77	114	92	94	116	89	89	97	111	101	125	114	73	96	120	92	90	99
1903	88	107	90	107	97	107	88	89	115	117	115	136	100	84	110	85	91	102
1904	78	100	78	81	93	94	104	82	98	----	90	122	77	84	103	73	71	89
1905	72	124	99	91	98	97	100	70	105	----	116	110	140	96	106	95	105	102
1906	90	129	103	79	121	87	89	85	99	----	116	119	73	88	109	100	108	100
1907	65	109	78	85	114	97	83	88	107	----	122	83	116	103	99	109	103	98
1908	65	94	71	95	89	84	83	65	98	88	88	114	88	85	96	67	97	86
1909	78	82	98	76	88	92	89	73	98	----	86	115	119	118	71	92	115	93
1910	82	96	90	93	93	88	106	74	85	----	87	36	90	93	97	85	104	87
1911	65	99	101	72	120	114	99	84	95	----	120	145	118	90	96	111	114	103
1912	105	108	112	123	110	106	89	84	91	----	112	76	143	111	90	95	104	104
1913	85	98	85	80	111	107	100	69	105	----	90	87	111	96	87	103	105	95
1914	91	94	84	87	92	93	90	78	79	----	91	89	96	89	93	80	96	89
1915	96	98	89	104	105	98	85	98	96	----	115	111	121	123	115	101	125	105
1916	88	94	91	76	76	97	108	88	78	----	90	88	104	104	91	94	110	92
1917	69	94	99	84	92	91	111	75	93	----	94	90	70	62	83	87	104	87
1918	65	90	85	86	88	90	88	79	79	----	93	108	107	90	82	103	97	89
1919	75	106	145	96	115	120	99	93	113	91	117	109	118	98	109	97	123	108
1920	96	99	121	115	108	93	83	106	114	----	120	89	114	78	107	99	98	102
1921	94	89	101	84	87	107	84	76	81	----	94	90	85	102	92	140	122	96
1922	104	115	127	116	74	83	99	89	101	125	106	90	100	81	79	95	98	99

TABLE 5.—*Percentages of annual rainfall in Pacific Coast States*

Year	The Dalles	Astoria	San Francisco	San Diego	Sacramento	Nevada City	Santa Barbara	Stockton	Mean
1850	--------	--------	75	82	102	--------	--------	--------	86
1851	--------	--------	67	78	79	--------	--------	--------	75
1852	--------	--------	113	123	141	--------	--------	--------	127
1853	87	--------	91	82	105	--------	--------	--------	91
1854	75	77	97	121	104	--------	--------	--------	95
1855	--------	103	113	116	97	--------	--------	--------	107
1856	--------	77	96	101	75	--------	--------	--------	87
1857	177	104	90	64	68	--------	--------	--------	101
1858	262	82	101	88	88	--------	--------	--------	124
1859	--------	106	92	63	88	--------	--------	--------	87
1860	128	92	91	95	103	--------	--------	--------	102
1861	174	120	109	82	113	--------	--------	--------	120
1862	98	79	166	120	144	--------	--------	--------	121
1863	85	122	65	31	64	--------	--------	--------	73
1864	--------	98	93	79	101	88	--------	--------	92
1865	--------	110	60	78	58	70	--------	--------	75
1866	--------	129	156	128	139	151	--------	--------	141
1867	--------	118	132	163	158	188	--------	156	152
1868	--------	75	130	116	102	118	86	107	105
1869	--------	90	97	114	95	101	65	108	96
1870	--------	93	70	45	54	92	63	44	66
1871	--------	129	118	59	99	119	81	118	103
1872	--------	96	97	52	100	113	57	108	89
1873	--------	96	80	135	95	88	62	73	90
1874	--------	105	97	113	94	102	67	104	97
1875	159	124	98	71	122	94	122	102	112
1876	93	110	101	75	95	98	91	83	93
1877	107	--------	51	84	44	55	47	48	62
1878	75	--------	143	144	123	100	167	121	125
1879	130	--------	132	153	118	127	81	99	120
1880	82	--------	129	106	167	129	161	125	128
1881	132	--------	102	52	108	89	45	70	85
1882	93	--------	80	101	95	85	68	74	85
1883	84	--------	66	83	71	71	89	97	80
1884	111	64	167	286	183	156	212	172	169
1885	77	72	107	60	108	76	94	66	83
1886	82	93	86	160	95	80	76	82	94

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TABLE 5.—*Percentages of annual rainfall in Pacific Coast States*—Con

Year	The Dalles	Astoria	San Francisco	San Diego	Sacramento	Nevada City	Santa Barbara	Stockton	Mean
1887	73	119	82	109	70	72	94	67	88
1888	70	89	99	120	97	71	147	89	96
1889	45	84	159	167	144	140	179	136	132
1890	74	76	110	83	110	114	85	85	92
1891	73	101	91	94	82	77	79	83	85
1892	72	91	95	95	124	114	106	102	100
1893	108	118	77	107	87	95	108	85	98
1894	108	115	105	45	119	112	55	153	102
1895	84	92	73	118	91	95	64	85	88
1896	101	122	117	91	132	127	103	112	113
1897	100	110	71	93	80	77	67	75	84
1898	46	89	40	48	53	44	40	49	51
1899	101	131	100	63	111	114	83	134	105
1900	82	110	66	60	94	80	58	100	81
1901	95	101	85	99	97	96	83	101	95
1902	105	112	82	119	94	90	98	86	98
1903	77	97	79	63	77	87	72	104	82
1904	96	115	106	69	110	125	114	115	106
1905	71	94	70	170	78	68	120	90	95
1906	90	106	113	155	161	151	153	182	139
1907	121	96	105	83	105	116	158	121	113
1908	49	74	71	89	59	58	93	68	70
1909	97	--------	135	147	130	140	237	142	148
1910	88	112	53	60	41	59	60	58	66
1911	54	77	112	122	110	118	168	134	112
1912	101	111	56	110	58	69	77	69	81
1913	85	92	68	76	75	85	102	77	82
1914	78	99	86	113	84	88	163	112	103
1915	96	103	101	142	93	110	142	120	113
1916	94	120	125	120	96	105	104	129	123
1917	76	--------	42	83	43	47	65	48	58
1918	72	--------	90	124	84	75	157	104	101
1919	92	--------	82	70	67	73	57	69	73
1920	68	105	78	80	77	102	76	90	84
1921	131	121	85	183	71	80	108	86	108
1922	--------	--------	111	96	96	120	123	136	114

TABLE 6.—*Annual rainfall of the Punjab*

[See Table 8, "A rainfall period equal to one-ninth the sun-spot period," D. A. University of Kansas Science Bulletin, Volume 13, No. 11]

Year	Amount	Per cent	Year	Amount	Per cent
1863	32.07	151	1891	19.34	91
1864	21.04	99	1892	26.17	123
1865	27.73	131	1893	32.59	153
1866	21.59	102	1894	34.23	161
1867	21.33	100	1895	20.34	96
1868	16.42	77	1896	14.47	68
1869	23.25	109	1897	18.72	88
1870	17.24	81	1898	19.81	93
1871	17.97	85	1899	8.89	42
1872	26.23	124	1900	26.36	124
1873	28.28	133	1901	15.17	71
1874	20.37	96	1902	14.01	66
1875	30.90	145	1903	17.39	82
1876	23.01	108	1904	15.87	75
1877	24.55	115	1905	14.87	70
1878	25.94	122	1906	20.84	98
1879	19.10	90	1907	15.52	73
1880	17.69	83	1908	25.16	118
1881	23.05	108	1909	21.64	102
1882	22.43	106	1910	17.68	83
1883	18.34	86	1911	15.44	73
1884	23.10	109	1912	15.37	72
1885	22.95	108	1913	17.64	83
1886	25.87	122	1914	25.28	119
1887	21.94	103	1915	11.70	55
1888	20.96	99	1916	19.62	92
1889	22.08	104	1917	31.67	144
1890	28.89	136	1918	10.00	47

Mean rainfall for period=21.25 inches.

TABLE 7.—*Periodogram of northern Europe*

Period in years	Intensity	h	A(1748)	B(1748)	Phase, July, 1901
					°
8	43	0.58	−35	−39	
8 1/6	129	1.75	−81	−41	
8 1/4	128	1.73	−90	+9	
8 1/3	149	2.02	−95	+23	
8 1/2	27	0.37	+7	+42	
8 3/4	60	0.81	−22	−66	
8 7/8	98	1.33	−81	−37	
9	86	1.17	−78	−29	200
9 1/8	62	0.84	−67	−22	112
9 1/6	77	1.04	−78	+11	39
9 1/3	37	0.50	−55	−1	321
9 1/2	26	0.35	−46	−1	217
9 3/4	62	0.84	−57	+54	26
10	170	2.30	−10	+130	202
10 1/8	199	2.70	+33	+137	114
10 1/4	172	2.32	−100	+85	109
10 1/2	20	0.27	−28	−35	64
10 3/4	24	0.33	−45	+29	
11	20	0.27	−7	+49	
11 1/4	17	0.23	−9	+44	
11 1/2	3	0.04	+14	+13	
11 3/4	65	0.88	+83	−50	
11 7/8	36	0.49	+29	−72	
12	59	0.80	+24	−89	
12 1/4	70	0.95	−44	−90	
12 1/4	57	0.77	−53	−74	
12 1/2	66	0.90	−97	+8	
12 3/4	66	0.90	−22	+103	
13	46	0.62	+24	+85	
13 1/2	66	0.90	+104	+17	
14	51	0.69	+78	−62	
15	184	2.50	−64	−193	252
15 1/3	268	3.64	−175	−172	215
15 1/2	297	4.03	−250	−76	150
15 2/3	324	4.40	−272	−2	96
15 3/4	430	5.83	−303	+135	55
16	255	3.46	−171	+195	329
17	41	0.56	+78	+77	
18	23	0.31	+83	+23	
19	29	0.39	−40	−100	
20	23	0.31	−70	+65	
21	19	0.26	+70	−66	
22	84	1.14	−141	−141	
23	142	1.92	−256	+97	
23 1/4	149	2.02	−246	+136	
23 1/2	129	1.75	−173	+202	
24	146	1.98	−82	+278	
25	116	1.57	+126	+238	
26	72	0.98	+208	+74	
27	73	0.99	+176	−149	
28	32	0.43	+29	−155	
29	23	0.31	−100	−96	
30	7	0.09	−79	+19	
31	10	0.14	−88	+71	
32	11	0.15	+107	−17	
34	50	0.68	−53	−234	
36	76	1.03	−309	−50	
37	115	1.56	−370	+145	
37 1/2	102	1.38	−308	+210	
38	112	1.52	−252	+313	
39	96	1.30	−120	+363	
40	93	1.26	+1	+367	
44	23	0.31	+198	+79	
48	19	0.26	+16	+207	

Mean intensity=74.

TABLE 8.—*Periodogram of eastern United States*

Period in years	Intensity	h	A(1820)	B(1820)	Phase, July, 1901
					°
8	36	0.94	+14	−46	
8 1/6	11	0.29	0	+27	
8 2/3	22	0.57	+9	+41	
9	117	3.05	+49	+84	60
9 1/3	125	3.26	+92	+41	265
9 2/3	174	4.53	+116	−63	104
9 3/4	134	3.49	+104	−51	82
10	119	3.10	+103	−36	17
10 1/4	160	4.17	+113	−57	297
10 1/3	113	2.94	+61	−81	249
10 1/2	130	3.39	+55	−100	217
11	1	0.03	−4	+10	
11 1/3	39	1.02	+66	−20	
12	40	1.04	+48	−59	
13	28	0.73	+63	−27	
14	94	2.45	+68	−117	224
14 1/3	96	2.50	+25	−135	130
15	83	2.16	−55	−125	54
15 1/2	70	1.82	−95	−82	301
16	11	0.29	−53	−7	
17	13	0.34	+54	−43	
18	29	0.76	−6	−96	
19	17	0.44	−61	−48	
20	10	0.26	−35	+52	
22	12	0.31	+69	−31	
24	10	0.26	+70	−29	
26	36	0.94	+137	−74	

TABLE 9.—*Periodogram of California and Oregon*

Period in years	Intensity	h	A(1850)	B(1850)	Phase, July, 1901
					°
8	674	2.252	+129	+163	
8 1/3	93	0.310	+77	+2	
8 2/3	4	0.010	+17	−4	
9	442	1.471	+173	+76	264
9 1/3	1,342	4.475	+307	+121	148
9 1/2	634	2.112	+152	−168	82
9 3/4	734	2.453	−97	−253	346
10	360	1.201	−150	−116	254
10 1/4	26	0.090	+42	−26	
11	96	0.320	−34	−102	
11 1/2	387	1.291	−135	−167	
12	404	1.351	−241	+10	
12 1/4	362	1.211	−124	+35	
12 1/2	609	2.032	−278	+102	
13	434	1.451	−109	+248	
14	307	1.021	+184	+167	
15	308	1.031	+186	−186	99
15 1/6	146	0.490	+85	−160	
15 1/2	193	0.640	+54	−201	
15 2/3	294	0.981	−28	−273	355
16	122	0.410	−78	−158	
17	130	0.430	−151	+122	
18	98	0.330	+139	+111	

TABLE 10.—*Periodogram of the Punjab*

Period in years	Intensity	h	A(1863)	B(1863)	Phase, July, 1901
					°
8	632	0.39	−77	−186	
8 1/3	228	0.14	−110	−50	
8 2/3	857	0.53	−59	+257	
9	1,295	0.80	+27	+323	
9 1/2	737	0.45	+33	+242	
10	1,607	0.99	+298	+268	330
10 1/4	2,250	1.39	+351	+319	60
10 1/2	2,138	1.32	+409	+216	251
11	1,530	0.94	+428	−45	
11 1/2	518	0.32	+239	−75	
12	185	0.11	+149	−65	
13	667	0.41	+225	+249	
14	2,392	1.80	+672	+134	268
15	3,218	1.99	+769	−365	166
15 1/6	3,171	1.96	+725	−435	142
15 2/3	4,478	2.95	+544	−923	94
16	3,840	2.37	+499	−857	76
17	2,800	1.73	−121	−892	
18	1,340	0.83	−310	−571	

TABLE 11.—*Length of record, normals, etc., for the stations used in Tables 3, 4, and 5*

Stations	Number of years	Normal	Remarks
TABLE 3		*Inches*	
Lund	160	17.18 20.58	1861 to 1910 means are from Swedish towns. Compiled by author.
Abo	131	23.79 22.39	Published mean. Beginning with 1803 Warsaw is substituted.
Montdidier	107		
Copenhagen	100	22.70	Compiled by author.[1]
Denmark (all stations)	60	26.42	Manuscript from Prof. Carl Ryder; published by author.[2]
Chilgrove	86	34.31	British Rainfall, 1919.
Utrecht	72	28.52	
London	60	25.59	Rainfall British Isles, Salter, p. 215.
Haverfordwest	60	48.03	Do.
Glengyle	60	91.84	Do.
Belfast	60	34.57	Do.
Four stations in Norway	49	49.72	Averaged from data given on pp. 64–65. Nedboriagttagelser i Norge (1918).
TABLE 4			
Charleston, S. C	91	48.59	
Washington, D. C	83	40.80	
Nashville, Tenn	58	47.89	
Savannah, Ga	72	50.06	
Philadelphia, Pa	103	42.90	
Pittsburgh, Pa	78	36.17	
Rochester, N. Y	93	33.34	
Albany, N. Y	97	38.39	New Orleans from Annual Summary of that station; all others from Climatological Data by Sections.
New York, N. Y	97	42.47	
Penn Yan, N. Y	62	28.99	
Baltimore, Md	106	40.20	
St. Paul, Minn	86	27.80	
New Orleans, La	76	56.30	
St. Louis, Mo	87	40.10	
Lebanon, Pa	82	44.45	
Cincinnati, Ohio	88	40.63	
Portsmouth, Ohio	97	42.47	
TABLE 5			
The Dalles, Oreg	55	16.50	
Astoria, Oreg	61	77.24	
San Francisco, Calif	73	23.25	
San Diego, Calif	73	9.63	Climatological Data of United States by Sections and manuscript data from Mr. E. A. Beals and Mr. E. L. Wells.
Sacramento, Calif	73	19.10	
Nevada City, Calif	59	54.61	
Santa Barbara, Calif	55	18.23	
Stockton, Calif	56	14.57	

[1] Kansas Univ. Sci. Bull. 12: 76, July, 1912.
[2] Kansas Univ. Sci. Bull. 12: 54, July, 1912.

THE VAPOR PRESSURE OF ICE AND OF WATER BELOW THE FREEZING POINT

By EDWARD W. WASHBURN

[National Research Council, Washington, Aug. 20, 1924]

INTRODUCTION

This communication embodies the results of a critical examination of the available vapor pressure data on ice and supercooled water, and was undertaken for the purpose of computing tables of vapor pressures for inclusion in International Critical Tables. At the request of the editor of the REVIEW, the author has added some footnotes in further explanation of some of the thermodynamic principles used.

THE VAPOR PRESSURE OF ICE

In preparing a table of vapor pressures of ice the older investigations on this subject can not be taken into account, owing, if for no other reason, to lack of definition of the temperature scales employed by the investigators. In computing the table given below, I have therefore based the calculations on the concordant measurements by (1) Weber (in the physical laboratory of the University of Leyden) and (2) Scheel and Heuse (at the Reichsanstalt). These investigations cover the range $-100°$ to $0°$ C.

The interpolation equation for this temperature range was obtained by integrating the Clausius-Clapeyron equation [1]

$$\frac{dp}{dT}=\frac{L_s}{(v-V)T} \qquad (1)$$

using the best available thermal data, as set forth below. In integrating the equation the perfect gas law was assumed for the vapor and the term Vdp, involving the volume, V, of the solid, was at first included in the integration. It was found, however, that the terms to which it gave rise in the integral were negligible. The integral was finally obtained in the following form:

$$\log_{10}p=\frac{A}{T}+B\log_{10}T+CT+DT^2+I \qquad (2)$$

where T is the absolute centigrade temperature and A, B, C, D, and I are constants.

The constant A was based upon the latent heat of vaporization of ice at 0° C., which was computed from Dieterici's value for the latent heat of vaporization of water at 0° (i. e., 2493 Int. Joules per gram) and Dickinson and Osborne's value [2] for the latent heat of fusion of ice at 0° (i. e., 79.76 ± 0.02 $cal._{20}$ per gram).

The constant B was based upon the value 0.5057 $cal._{20}$, the heat capacity of ice [3] per gram at 0° C. and the value 0.457 $cal._{20}$ the heat capacity of water vapor [4] per gram at 0° C.

The integration constant, I, was evaluated by taking the well-established value $p=4.579$ mm. at 0°, and the constants C and D were evaluated from two experimental values for p, one in the neighborhood of $-100°$ based upon Weber's measurements and the other in the neighborhood of $-50°$ based upon concordant measurements by Weber and by Scheel and Heuse.

The equation thus obtained is

$$\log_{10}p=\frac{-2445.5646}{T}+8.2312\log_{10}T$$
$$-0.01677006T+1.20514\times10^{-5}\cdot T^2-6.757169 \qquad (3)$$

Using this equation to obtain p_{calc}, a deviation graph, $p_{calc}-p_{obs}$, was then prepared and is displayed in Figure 1. An examination of this graph shows that the equation satisfactorily expresses the experimental data throughout the region from $-100°$ to $-20°$. Between $-20°$ and 0° the only extensive experimental data available are those of Scheel and Heuse, which deviate rather widely from the calculated values for this region. In a later paper [5] by the same authors, attention is called to the fact that

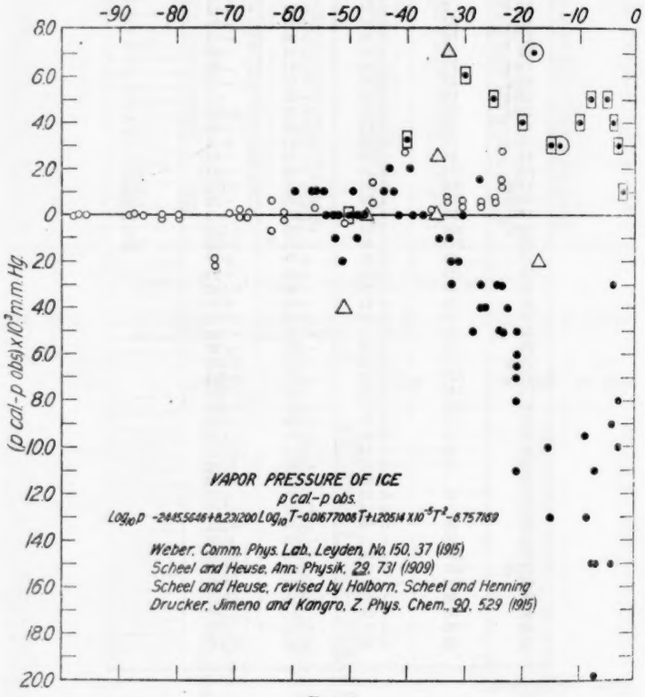
-90 -80 -70 -60 -50 -40 -30 -20 -10 0
80 60 40 20 0 20 40 60 80 100 120 140 160 180 200
(p cal-p obs)x10³ m.m Hg
VAPOR PRESSURE OF ICE
p cal-p obs.
Log10p -2445.5646+8.2312 Log10T-0.01677006T+1.20514 X10⁻⁵T²-6.757169
Weber, Comm. Phys. Lab., Leyden, No. 150, 37 (1915)
Scheel and Heuse, Ann. Physik, 29, 731 (1909)
Scheel and Heuse, revised by Holborn, Scheel and Henning
Drucker, Jimeno and Kangro, Z. Phys. Chem., 90, 529 (1915)

FIG. 1

our knowledge of the relation between the platinum scale (platinum-resistance thermometer) and the gas-thermometer scale in this interval is still in a very unsatisfactory state and that consequently the measurements in this region require revision. Some such revision appears to have been made by the Reichsanstalt, for, in the recent book by Holborn, Scheel, and Henning [6] quite different values are given for the vapor pressure of ice between $-50°$ and 0°. The nature of the revision made by them is not indicated, but, judging from the discussion referred to above, the revision is perhaps based upon a modification of the Callender interpolation equation for the platinum-resistance thermometer. Their revised values are also plotted in Figure 1. While the revised values agree somewhat better with equation (3), the differences are now in the opposite direction and are still much larger than can be accounted for by any obvious source of error in the pressure measurements.

[1] p=vapor pressure; T=absolute temperature; L_s=latent heat of sublimation per gram-mole; v, V=orthobaric volumes per gram-mole for the vapor and liquid, respectively. For a simple derivation of this equation, see Washburn's "Principles of Physical Chemistry," p. 482.
[2] Dickinson and Osborne, Bull. Bur. Stands. 12, 76 (1915).
[3] Dickinson and Osborne, loc. cit.
[4] Estimated.
[5] Scheel and Heuse, Ann. Physik. 31, 733 (1910).
[6] "Wärmetabellen der Physikalisch-Technischen Reichsanstalt," Braunschweig, 1919.

It seems, therefore, necessary to reject the experimental data in this region on account of the uncertainty in the temperature measurements and to assume that the calculated values are the correct ones. This is the more justifiable since the equation has a sound thermodynamic basis and the constants C and D, which are the only ones determined empirically, have practically no influence upon the calculation in this region; that is, the omission of the terms containing C and D and a re-evaluation of I for this range gives an equation yielding substantially the same values of p.

THE VAPOR PRESSURE OF LIQUID WATER BELOW THE FREEZING POINT

Having established the vapor pressure table for ice, the most reliable method of arriving at the values for the vapor pressure of undercooled water is through the thermodynamic relation which connects the two sets of vapor pressures. This relation, which is a direct consequence of the Second Law of Thermodynamics,[7] is:

$$d \log_e \frac{p_w}{p_I} \equiv d \log_e r = \frac{-L_F dT}{RT^2} \tag{4}$$

where p_w and p_I are the respective vapor pressures of water and of ice at the absolute temperature T, L_F is the latent heat of fusion per mole of ice at $T°$ and R is the gas constant. In order to integrate this equation, we must first express L_F as a function of the temperature. The Law of Conservation of Energy gives us the following function:

$$L_F = L_{F_0} + at + 1/2\ bt^2 + 1/3\ ct^3 \tag{5}$$

where t is the centigrade temperature, and a, b, and c are constants which can be obtained and numerically evaluated from the following empirical relations:

$$s_w = 1.0092 - 0.001080\ t + 0.000036\ t^2 \tag{6}$$

where s_w is the heat capacity of liquid water in cal.$_{15}$ per gram: [8]

$$s_I = 0.5952 + 0.001861\ t \tag{7}$$

where s_I is the heat capacity of ice [9] in the same units:

$$\Delta s = 18.015\ (s_w - s_I) = a + bt + ct^2 \tag{8}$$

$$= 9.079 - 0.05300t + 0.00065t^2 \tag{9}$$

and

$$L_{F_0} = 1435.5,^{10}\ \text{cal.}_{15}\ \text{mole}^{-1} \tag{10}$$

[7] The Second Law of Thermodynamics is the mathematical formulation of the principle that the autogenous flow of heat is always from a higher to a lower temperature, never in the reverse direction. This law, applied to the vaporization of a solid or a liquid having a low vapor pressure, yields the relation (Washburn, loc. cit.):

$$d \log_e p = \frac{L d T}{R T^2}$$

where p is the vapor pressure; L, the latent heat of vaporization per mole (both at $T°$ absolute); and R is the gas constant. Thus, for ice and water, respectively, this equation becomes

$$d \log_e p_I = \frac{L_s d T}{R T^2}$$

and

$$d \log_e p_w = \frac{L_v d T}{R T^2}$$

Subtracting the first equation from the second gives us equation (4), since, according to the law of the conservation of energy,

$$L_s - L_v = L_F$$

The conservation law also gives us the relation

$$\frac{dL_F}{dT} = s_w - s_I$$

the integral of which is our equation (5). (Vide Washburn loc. cit., p. 307.)

[8] Numerical coefficients deduced from the data of Barnes and Cooke [Phys. Rev. *16*, 65 (1903)] at 5°, 0°, and −5°C.

[9] Equation obtained by Dickinson and Osborne, loc. cit., valid between −40° and 0° C.

[10] From the determination by Dickinson and Osborne, loc. cit.

Combining equation (5) with (4), integrating, expanding the logarithm term in powers of t, and performing the divisions indicated so as to obtain all terms except the first in powers of t, yields finally the relation,

$$R \log_e r = \frac{-L_{F_0} t}{T_0 (T_0 + t)} - \frac{1/2\, a}{T_0^2} t^2 + \left[\frac{2/3\, a}{T_0} - \frac{1/2\, b}{T_0^2}\right] t^3 - \left[\frac{3/4\, a}{T_0^4} - \frac{1/4\, b}{T_0^3} + \frac{1/2\, c}{T_0^2}\right] t^4 \tag{11}$$

Putting $R = 1.9869$ cal.$_{15}$ deg.$^{-1}$ mole^{-1}, $T_0 = 273.1°$C, and evaluating a, b, and c, as indicated above, gives finally

$$\log_{10} p_w = \frac{-1.1489t}{(273.1 + t)} - 1.330 \times 10^{-5}\ t^2 + 9.084 \times 10^{-8}\ t^3 - 1.08 \times 10^{-9}\ t^4 + \log_{10} p_I \tag{12}$$

It will be noticed that no vapor pressure data are required in deriving this equation.

For an accuracy of 0.001 mm. Hg, in the value of p_w, the t^4 term is negligible down to −40°, the t^3 term down to −11°, and the t^2 term down to −2°. All of the numerical constants in the equation are known to two more significant figures than are required for an accuracy of 0.001 mm. of Hg in p_w.

When we compare the values of $p_I - p_w$ calculated by means of equations (12) and (3) with the corresponding differences between the directly measured values obtained by the Reichsanstalt, we find that the maximum value of $(p_I - p_w)$ calc. $- (p_I - p_w)$ obs. is only 0.004 mm. at −16° and decreases as 0° is approached. In other words, the pressure measurements of the Reichsanstalt are consistent, although, as explained above, the corresponding temperatures are uncertain, an uncertainty in the temperature scale having a much smaller influence on $p_w - p_I$ than it does on p_w and p_I separately.

THE VAPOR PRESSURE OF ICE UNDER ATMOSPHERIC PRESSURE

The measured values of the vapor pressure of ice and the table given below, which is based upon these values, are for ice under its own vapor pressure. In contact with the atmosphere, ice has a slightly higher vapor pressure than when in contact only with its own vapor. In order, therefore, to obtain the vapor pressure of ice under atmospheric conditions, it is necessary to *add* a small correction to the values given in Table 1 below. This correction expressed in per cent, $100\,\frac{\Delta p}{p}$, is given by the equation

$$100\,\frac{\Delta p}{p} = \frac{100\,V}{RT}\,(B - p) \tag{13}$$

where V is the molal volume of ice at $T°$ abs. and B is the barometric pressure. V is in general a function of T, but by employing an average value the above equation may, for all practical purposes, be written

$$100\,\frac{\Delta p}{p} = \frac{20}{T} \tag{14}$$

Thus, for example, to find the vapor pressure of ice at −5° C., under atmospheric pressure,

$$100\,\frac{\Delta p}{p} = \frac{20}{268} = 0.075\%$$

From Table I we find $p = 3.013$ at $-5°$, which, increased by 0.075%, gives 3.015, the vapor pressure of ice in contact with the atmosphere at $-5°$ C.

THE VAPOR PRESSURE OF WATER IN EQUILIBRIUM WITH THE ATMOSPHERE

Just as in the case of ice, the vapor pressure of water in contact with the atmosphere differs from its vapor pressure when in contact with its own vapor only. For water below 0° C. the correction may, for all practical purposes, be computed from equation (14). For higher temperatures, the following more exact equations may be employed:

$$100\,\frac{\Delta p}{p} = 0.0775 - 3.13\times10^{-4}\,t \text{ (valid up to } t = 40° \text{ C.)} \quad (15)$$

and

$$100\,\frac{\Delta p}{p} = 0.0652 - 8.75\times10^{-5}\,p \text{ (valid above 50° C.)} \quad (16)$$

In these equations both the effect of the external pressure, as such, and the effect of dissolved air are taken into account. At high temperatures (70°–80° C.) this correction amounts to more than 0.1 mm.

TABLE 1.—*The vapor pressure of ice*

Computed from the equation

$$\log_{10} p = \frac{-2445.5646}{T} + 8.2312\log_{10}T - 0.01677006\,T + 1.20514\times10^{-5}\,T^2 - 6.757169 \text{ mm. Hg.}$$

Based upon the measurements of Weber (Comm. Phys. Lab. Leyden No. **150**, 37 1915]) and Scheel and Heuse (Ann. Physik **29**, 731 [1909]).

$T = 273.1 + t$

−90° to −30°. unit, 0.001 mm. Hg

t	0	1	2	3	4	5	6	7	8	9
° C.										
−90	0.07_0	0.05_8	0.04_8	0.04_0	0.03_3	0.02_7	0.02_2	0.01_8	0.01_5	0.01_2
−80	0.40	0.34	0.29	0.24	0.20	0.17	0.14	0.12	0.10	0.08_4
−70	1.94	1.67	1.43	1.23	1.05	0.90	0.77	0.66	0.56	0.47
−60	8.0_8	7.0_2	6.1_4	5.3_4	4.6_4	4.0_2	3.4_9	3.0_2	2.6_1	2.2_5
−50	29.5_8	26.1	23.0	20.3	17.8	15.7	13.8	12.1	10.6	09.2_3
−40	96.6	86.2	76.8	68.4	60.9	54.1	48.1	42.6	37.8	33.4
−30	285.9	257.5	231.8	208.4	187.3	168.1	150.7	135.1	120.9	108.1

−30° to 0°. mm. Hg

t	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
° C.										
−29	0.317	0.314	0.311	0.307	0.304	0.301	0.298	0.295	0.292	0.289
−28	0.351	0.348	0.344	0.341	0.337	0.334	0.330	0.327	0.324	0.320
−27	0.389	0.385	0.381	0.377	0.374	0.370	0.366	0.362	0.359	0.355
−26	0.430	0.426	0.422	0.418	0.414	0.409	0.405	0.401	0.397	0.393
−25	0.476	0.471	0.467	0.462	0.457	0.453	0.448	0.444	0.439	0.435
−24	0.526	0.520	0.515	0.510	0.505	0.500	0.495	0.490	0.486	0.481
−23	0.580	0.574	0.569	0.563	0.558	0.552	0.547	0.541	0.536	0.531
−22	0.640	0.633	0.627	0.621	0.615	0.609	0.603	0.597	0.592	0.586
−21	0.705	0.698	0.691	0.685	0.678	0.672	0.665	0.659	0.652	0.646
−20	0.776	0.769	0.761	0.754	0.747	0.740	0.733	0.726	0.719	0.712
−19	0.854	0.846	0.838	0.830	0.822	0.814	0.806	0.799	0.791	0.783
−18	0.939	0.930	0.921	0.912	0.904	0.895	0.887	0.879	0.870	0.862
−17	1.031	1.021	1.012	1.002	0.993	0.984	0.975	0.966	0.956	0.947
−16	1.132	1.121	1.111	1.101	1.091	1.080	1.070	1.060	1.051	1.041
−15	1.241	1.230	1.219	1.208	1.196	1.186	1.175	1.164	1.153	1.142
−14	1.361	1.348	1.336	1.324	1.312	1.300	1.288	1.276	1.264	1.253
−13	1.490	1.477	1.464	1.450	1.437	1.424	1.411	1.399	1.386	1.373
−12	1.632	1.617	1.602	1.588	1.574	1.559	1.546	1.532	1.518	1.504
−11	1.785	1.769	1.753	1.737	1.722	1.707	1.691	1.676	1.661	1.646
−10	1.950	1.934	1.916	1.899	1.883	1.866	1.849	1.833	1.817	1.800
−9	2.131	2.112	2.093	2.075	2.057	2.039	2.021	2.003	1.985	1.968
−8	2.326	2.306	2.285	2.266	2.246	2.226	2.207	2.187	2.168	2.149
−7	2.537	2.515	2.493	2.472	2.450	2.429	2.408	2.387	2.367	2.346
−6	2.765	2.742	2.718	2.695	2.672	2.649	2.626	2.603	2.581	2.559
−5	3.013	2.987	2.962	2.937	2.912	2.887	2.862	2.838	2.813	2.790
−4	3.280	3.252	3.225	3.198	3.171	3.144	3.117	3.091	3.065	3.039
−3	3.568	3.539	3.509	3.480	3.451	3.422	3.393	3.364	3.336	3.308
−2	3.880	3.848	3.816	3.785	3.753	3.722	3.691	3.660	3.630	3.599
−1	4.217	4.182	4.147	4.113	4.079	4.045	4.012	3.979	3.946	3.913
−0	4.579	4.542	4.504	4.467	4.431	4.395	4.359	4.323	4.287	4.252

TABLE 2.—*The vapor pressure of liquid water from −16° C. to 0° C. (in mm. Hg)*

Computed from Table 1 with the aid of the thermodynamic equation

$$\log_{10}\frac{p_w}{p_1} = \frac{-1.1489\,t}{273.1+t} - 1.330\times10^{-4}t^2 + 9.084\times10^{-4}t^3$$

t	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
° C.										
−15	1.436	1.425	1.414	1.402	1.390	1.379	1.368	1.356	1.345	1.334
−14	1.560	1.547	1.534	1.522	1.511	1.497	1.485	1.472	1.460	1.449
−13	1.691	1.678	1.665	1.651	1.637	1.624	1.611	1.599	1.585	1.572
−12	1.834	1.819	1.804	1.790	1.776	1.761	1.748	1.734	1.720	1.705
−11	1.987	1.971	1.955	1.939	1.924	1.909	1.893	1.878	1.863	1.848
−10	2.149	2.134	2.116	2.099	2.084	2.067	2.050	2.034	2.018	2.001
−9	2.326	2.307	2.289	2.271	2.254	2.236	2.219	2.201	2.184	2.167
−8	2.514	2.495	2.475	2.456	2.437	2.418	2.399	2.380	2.362	2.343
−7	2.715	2.695	2.674	2.654	2.633	2.613	2.593	2.572	2.553	2.533
−6	2.931	2.909	2.887	2.866	2.843	2.822	2.800	2.778	2.757	2.736
−5	3.163	3.139	3.115	3.092	3.069	3.046	3.022	3.000	2.976	2.955
−4	3.410	3.384	3.359	3.334	3.309	3.284	3.259	3.235	3.211	3.187
−3	3.673	3.647	3.620	3.593	3.567	3.540	3.514	3.487	3.461	3.436
−2	3.956	3.927	3.898	3.871	3.841	3.813	3.785	3.757	3.730	3.702
−1	4.258	4.227	4.196	4.165	4.135	4.105	4.075	4.045	4.016	3.986
−0	4.579	4.546	4.513	4.480	4.448	4.416	4.385	4.353	4.320	4.289

TEMPERATURE LAG OF THE OCEANS

By W. J. HUMPHREYS

[Weather Bureau, Washington, D. C.]

From time to time we see the assertion that any appreciable change in the temperature of the ocean, such, for instance, as might result from a change in the solar constant, persists, in large measure, over a period of years. These assertions, however, are not backed up by sound theory, but based, if upon anything at all, upon a few observations, which, for the particular long-range forecast, or other objects in view, it is convenient to assume explained in the alleged manner.

It may be helpful, therefore, to compute, according to known physical laws and constants, how great we reasonably may expect such lags to be.

Owing to wave action and convection, temperature changes of the ocean are not confined to the surface, but penetrate in approximately full magnitude to an appreciable depth. For calculation it is here tentatively assumed that an exactly equal change extends down 20 meters, and that beyond this depth there is no change. It is believed that this assumption is of the proper order. Anyhow, the results will be correct to within an experimental factor.

As is well known, the earth maintains its average balance between heat gained and heat lost, by radiating, in amount, as would a black body of the same size at the absolute temperature 260°.[1] It is also known that, on the average, temperature changes are roughly the same at the surface and all the way up through the troposphere, or convective portion of the atmosphere. Hence, if the surface of the earth should be kept at a slightly different temperature than heretofore, its planetary blackbody temperature would also be altered in the same sense and to about the same extent.

The surface temperature of the land has a shorter time lag than that of the ocean, owing to permanency of position, lack of convection, and the small, as compared with water, specific heat of soil and rock. Actually, therefore, the temperature lags of the earth as a whole are less than they would be if there were no land at all, but for islands and many coastal regions not greatly less. Hence, to obtain the upper limit solution of the problem this land effect will be omitted. Perhaps this effect can best be

[1] Abbot and Fowle, Annals Astrophys. Obs. Smithsonian Inst., 2. p. 175.

(To face p. 491)

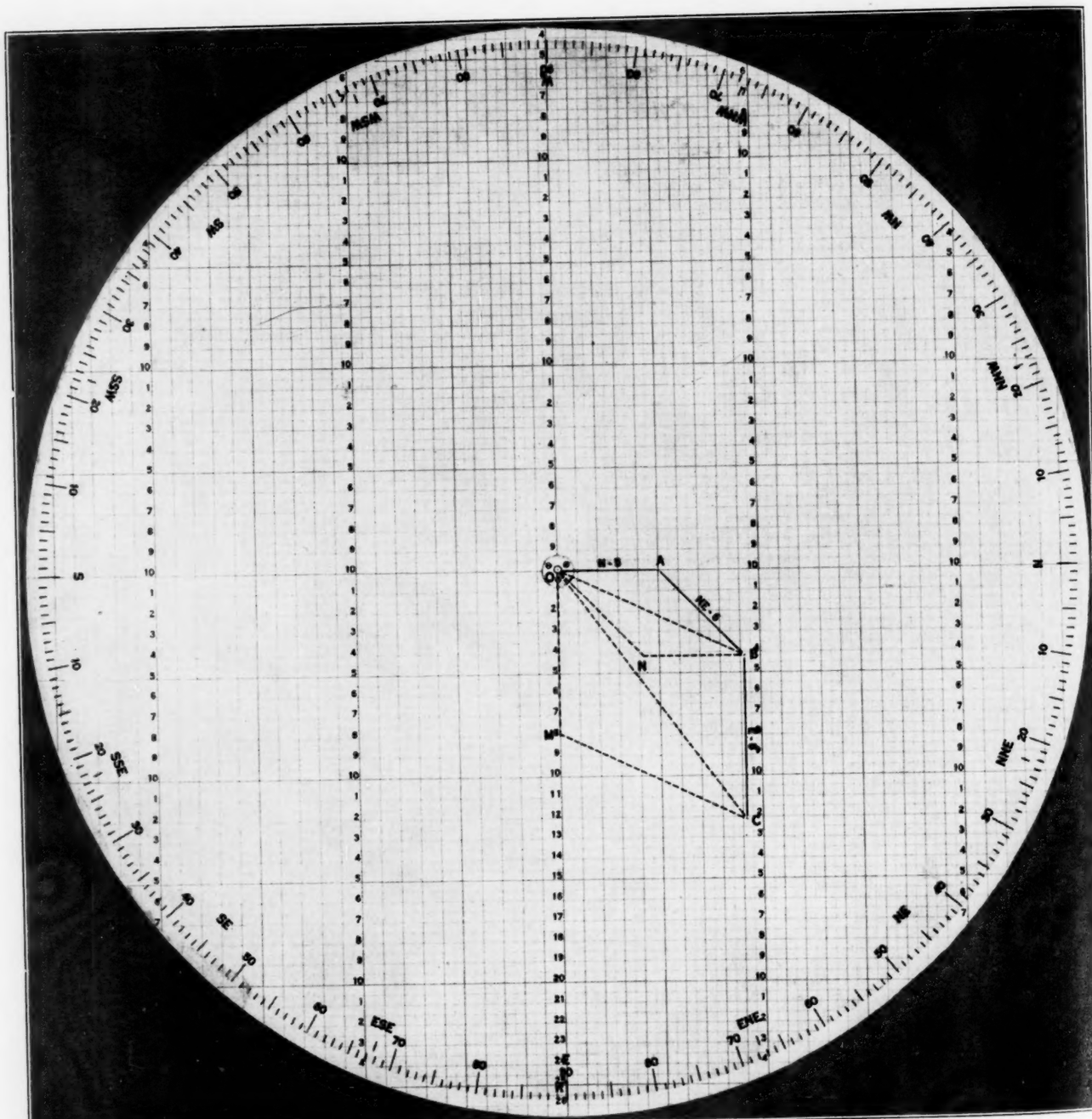

FIG. 1.—Plotting board for compounding vector quantities

treated as a correction term of one or another value as circumstances may determine.

Let, then, the oceans become warmer (if cooler the method of calculation would be the same) than is their wont by 1° C. from the surface to the depth of 20 meters, a storage of 2,000, approximately, calories per square centimeter of surface, and let the previous temperatures remain unchanged below this level. In what times, under normal conditions, will half, three-fourths, and nine-tenths of this added heat be lost and the excess temperature have fallen to 0.5° C., 0.25° C., and 0.1° C. respectively?

Since the loss of heat by radiation per square centimeter of flat surface, or its equivalent, of a black body is $1.27\times 10^{-12}\theta^4$ calories per second, in which θ is the absolute temperature, it follows that the net rate, calories per second, at which the stored up heat Q, is lost per square centimeter of ocean surface is the difference between the rates of total loss and total gain; that is, in symbols

$$dQ=\frac{1.27}{10^{12}}\left\{\theta^4-(260)^4\right\}dt,$$

in which t is the time in seconds.

If m is the mass of water warmed, s its specific heat, then

$$dQ=msd\theta$$

but in this case $m=2{,}000$ and $s=1$. Hence, substituting

$$\frac{d\theta}{\theta^4-(260)^4}=\frac{1.27}{2\times 10^{15}}\,dt$$

If, as assumed, the initial planetary temperature is 261° absolute, then the time in seconds for the given mass of water to cool to θ_1 is found by the equation

$$\int_{\theta_1}^{261}\frac{d\theta}{\theta^4-(260)^4}=\frac{1.27}{2\times 10^{15}}\int_0^t dt$$

or

$$\left[\log_e\left(\frac{\theta-260}{\theta+260}\right)^{\frac{1}{4(260)^3}}\right]_{\theta_1}^{261}-\frac{1}{2(260)^3}\left[\tan^{-1}\frac{\theta}{260}\right]_{\theta_1}^{261}=\frac{1.27}{2\times 10^{15}}\,t$$

in which t, as explained, is seconds, and the angle in radians.

The required times—time to lose, under normal conditions, half, three-fourths, and nine-tenths of the accumulated heat—are found by substituting for θ_1 in this last equation 260.5, 260.25, and 260.1, respectively. The results are

$\theta_1=$	260.5°	260.25°	260.1°
t, days =	178.958	358.287	595.625

Obviously, then, the temperature lags of the ocean incident to variations of incoming radiation are not very great, save for small and comparatively ineffective residuals.

GRAPHICAL METHOD OF COMPOUNDING VECTORS

By WILLIAM C. HAINES

[Weather Bureau, Washington, D. C., August, 1924]

The composition of vector quantities may be accomplished by either one of two methods; namely, the analytical method or the graphical method.

The analytical method of compounding vector quantities is expressed by the formulae:

$$\tan\theta=\frac{Y}{X}=\frac{r_1\sin\alpha_1,+r_2\sin\alpha_2+r_3\sin\alpha_3+\ \ldots}{r_1\cos\alpha_1,+r_2\cos\alpha_2+r_3\cos\alpha_3+\ \ldots}$$

$$\mathrm{R}\quad=\sqrt{X^2+Y^2}$$

where r_1, r_2, r_3 . . . are vectors, α_1, α_2, α_3, . . . are, respectively, the angles which the vectors make with the X axis and θ is the angle the resultant, R, makes with X axis. X and Y are $\Sigma r\cos\alpha$ and $\Sigma r\sin\alpha$, respectively. The composition of vectors by this general method is both tedious and laborious, but this is the proper method to use where mathematical accuracy is required.

The graphical method is accomplished by forming a parallelogram with two of the vectors as sides. The diagonal of this parallelogram and the third vector is taken as the sides of a second parallelogram, etc. The diagonal of the last parallelogram formed is the resultant. The accuracy of the result of this method depends entirely upon the precision with which the vectors are laid off. The writer has devised a simple graphical method by which vectors may be compounded quickly and with surprising accuracy. It is accomplished by means of a so-called plotting board somewhat similar to the one used in connection with our pilot balloon work, except that it is smaller in size.

The plotting board consists of an ordinary drawing board, over the central portion of which is glued a circular sheet of millimeter cross-section paper. Upon this board is mounted a circular celluloid protractor, fastened by a brass bearing at the center. The protractor is graduated in degrees; also, directions to 16 points of the compass are indicated to facilitate the compounding of wind vectors. The celluloid disc should be 50 or 60 cm. in diameter and frosted on one side so that it will take pencil marks readily and still be transparent. An initial line OR (see fig. 1) and scale are marked on the cross-section paper base. Other supplementary scales are indicated, the advantage of which will be explained later.

The use of this graphical method is made clear by the following simple example: Suppose we are to find the resultant direction and velocity of the vectors N–5, NE–6, and E–8.

First step: Set the north point of the protractor on the initial line OR, and with a pencil mark the point A on the protractor at a distance of 5 from the center, as shown by the scale along the line OR. Next turn the protractor to set NE on the line OR, then take the length of the second vector, or 6 from the point A parallel to the line OR, marking the point B on the protractor as the end point of the second vector. In reality a parallelogram OABN is thus formed with the N–5 and NE–6 vectors as sides; therefore the diagonal OB is the

resultant of these two vectors. Second step: Turn the protractor and set E on the line OR, and mark the point C on the protractor at a distance of 8 (length of third vector) from the point B parallel to the line OR. By this step parallelogram OBCM is formed with OB and BC as sides and OC as the diagonal. Keeping in mind the parallelogram law, it is obvious that OC is the resultant of the vectors N–5, NE–6, and E–8. Perhaps this may be seen more readily by referring to the polygon law. Considering the polygon OABC, it is clear that OC is the resultant.

When the protractor is turned so that point C is on the initial OR, the length and direction of the resultant is indicated on the scale and the protractor, respectively.

In short, the procedure of compounding vectors by this method amounts to setting the protractor so that the angle or direction of the vector to be considered lies on the initial line of the scale. The length of the vector is then laid off on the protractor from the end point of the preceding vector parallel to the initial line, and its end is indicated by a point, from which the next vector is laid off. The first vector is laid off from the center along the initial line of course. The resultant vector is the line from the origin or center to the end point of the last vector. Both its direction and magnitude are readily determined by placing the end point of the last vector over the initial line.

The millimeter cross-section paper and supplementary scales referred to above enable the operator to determine quickly and accurately the end points of the various vectors when they are far removed from the initial line OR. In this way results of considerable accuracy may be obtained without any computation.

This method of compounding vectors has been in use for the past two years and found to be especially advantageous in determining the mean wind direction; that is, the resultant direction where the strength of the wind is not considered, the various directions being considered as unit vectors.

For obtaining resultant winds, the aerological division has adopted a system suggested by Mr. H. P. Parker, of the aerological station at Broken Arrow, Okla., In this system the sums of the north and west components are obtained by the analytical method, and from these components the resultant direction and velocity of the wind are obtained graphically.

In compounding vectors by either the analytical or the graphical method, opposite directions should be canceled, thereby reducing the number of vectors to be considered.

WHY AN OAK IS OFTEN STRUCK BY LIGHTNING; A METHOD OF PROTECTING TREES AGAINST LIGHTNING

By ROY N. COVERT

[Weather Bureau, Washington, September 2, 1924]

It is desired to consider first what the factors are which determine the relative liability to lightning damage of trees, as determined by their location, the character of the soil in which they grow and its moisture condition, the electrical conductivity of the wood itself, etc.

As a general statement the tree which is a relatively good electrical conductor, and has a root system which is widespread, or which reaches deep into moist soil, is the one which is in most danger of being struck by lightning. No tree is immune, however.

Following are the factors which govern, as determined by careful studies made in western Europe of the effects of lightning on trees:[1]

(*a*) Among trees of the same kind the one which stands well above its neighbors is in most danger, even in a dense forest. This dominant position may be due to the greater height of the tree or be the result of the configuration of the ground.

(*b*) Trees growing in the open, either singly or in small groups, are in more danger than those in the dense forest or other thick stand of timber.

(*c*) Trees growing along avenues or in the border of a wood are also struck by lightning more often than those in thick woods.

(*d*) A tree growing in moist soil—that is, along the banks of a stream or a lake, or close to some other source of moisture—is a better conductor for lightning than one growing in drier soil.

(*e*) Trees growing in loam and sandy soils are struck much more frequently than those in clay, marl, and calcareous soils. Oaks grow mostly in loam and sandy soils.

(*f*) Sound trees in general are less likely to be seriously damaged than those with rotten wood. If the sound tree is also a relatively good conductor, lightning will go to earth easily, but rotten wood is a poor conductor of electricity so that the passage of the lightning current through this nearly nonconducting portion often results in a shattering of the tree and when dry the tree may be set on fire.

(*g*) Starchy trees, of which the oak is a good example, are better conductors of electricity than oily trees like the beech. The conifers are intermediate. Experiments made by Jonesco of the Württemburg Society of Natural Science gave the following results:

One turn of a Holz's electric machine passed the spark through oak wood, five turns through poplars and willows, and 12 to 20 turns through beech.

From the foregoing we learn that an oak is decidedly a good conductor of electricity, so far as trees go; that it grows in loam and sandy soils where trees are most frequently struck by lightning; and, furthermore, it is an excellent example of a tap-rooted tree with its root system extending deep into the soil, all of which qualities place the oak in great danger of lightning damage as compared with other trees. The following question is therefore pertinent:

What do statistical studies of the damage of trees by lightning show with regard to the relative frequency with which oaks are struck as compared with other trees?

The following figures were taken from Schlich's Manual of Forestry, Volume IV, entitled Forest Protection, by W. R. Fisher:

Trees struck in the Lippe-Detmold forest, Germany, from 1874–1890:

	Oak	Beech	Spruce	Pine	Others
Percentage of trees	11	70	13	6	----
Trees struck	310	33	39	110	30
Relative frequency [1]	60	1	6	37	----

[1] A previous discussion on kind of trees struck by lightning will be found on pp. 64–69 of Wea. Bu. Bull. No. 26, Lightning and the Electricity of the Air, McAdie and Henry, Washington, 1899.

Results of 15 years of observations published in the Revue des Faux et Forets:

	Oak	Beech	Spruce	Pine	Others
Percentage of trees	11	70	13	6	
Trees struck	159	21	20	59	20
Relative frequency	48	1	5	33	

Observations in the Bavarian State forests, 1887–1890:

	Oak	Beech	Spruce	Pine	Others
Percentage of trees	1.8	10.8	41.5	30.8	15.1
Trees struck	61	7	155	131	
Relative frequency	52	1	6	7	

[1] Relative frequencies are based on 1 for the beech, so that during the period covered by the observations 1 beech tree was struck to 60 oaks, 6 spruce, and 37 pine, each kind of tree being assumed to be present in equal numbers.

Other more recent studies confirm in general the above results, which show that the oak is struck much more frequently than other kinds of trees, with the possible exception of the poplar, which does not appear to have been present in the Lippe-Detmold forest. The list of trees also subject to lightning damage includes the elm, ash, and gum, while those least attractive to lightning are the chestnut, maple, alder, and mountain ash. Those intermediate are the apple, cherry, linden, and walnut, but no tree is immune.

As before stated, an unsound tree containing rotted portions is likely to be damaged to a greater extent than a sound tree, or one which has received surgical treatment, which introduces highly conducting metal into the tree in place of the rotted wood with its low conductivity.

The metal cables and rods quite often used in modern tree surgery to protect the trees against wind damage and decay, while serving in a minor way as conductors and furnishing some protection against lightning, can by no means be considered as a substitute for the thorough protection which it is possible to obtain by rodding, a more recent development than tree surgery. The rodding of trees, especially valuable ones, or those which involve the safety of a building or of animals, is now advocated by the Bureau of Standards, the Weather Bureau, the National Board of Fire Underwriters, the Ontario Department of Agriculture, and others.

In this connection the following is quoted from a new bulletin in process of preparation, entitled "Protection Against Lightning of Buildings and Farm Property":

Protection of trees.—If a building is more or less surrounded by high trees, these trees protect the building to quite an extent from lightning. This is especially true of deep-rooted trees, which are more liable to damage than others. Poplars, oaks, pines, elms, ash, etc., are of this kind. But the trees should be considered only as an additional protection to the building, and the customary equipment should be provided for the latter. Large, full-grown trees near a dwelling are valuable as a rule, and if it is desired to protect them against lightning, a few of the higher ones should be rodded as follows:

Place an air terminal in the top of the tree, but not so high as to be insecure, and ground it through one or two down conductors, the number depending upon the size of the tree. Screw fasteners with a long shank are desirable for holding the down conductors in place along the tree trunk in preference to a rigid fastening. One of the grounds provided for the conductors on the building may be used if convenient, or separate ones constructed at the foot of the trees. In order that a lightning discharge shall not damage the root system of the tree protected, it is generally advisable to construct shallow grounds, essentially as described under "stranded-cable grounds." It is realized that the growth of trees will make it difficult at times to maintain the rodding, and its extension, partial renewal, or repair will occasionally be needed, especially on the younger trees, but less so on the older trees, which change but little from year to year and are probably the most valuable and largest of a group and to be rodded in preference to the others. It is our conviction, however, that the additional protection of both trees and adjacent building often makes the trouble and expense worth while.

SOME FEATURES OF THE CLIMATE OF ALASKA [1]

By MELVIN B. SUMMERS

[Weather Bureau, Seattle, Wash.]

Less than a generation ago the popular conception of Alaska was that of a land of perpetual ice and snow, infested with polar bears, and inhabited by a race of beings who dwelt in snow and ice houses and subsisted on the blubber and flesh of walrus, seal, and other animals native to a frigid climate. So fixed had this idea become that even to-day, after considerably more than a billion dollars of wealth has been wrested from the Territory through mine, forest, field, and sea, there are those who find difficulty in divorcing these preconceived opinions from their minds.

It is a surprise to many people to learn that tropical daytime temperatures are recorded in Alaska every summer, and that there are parts of the Territory, notably in the Aleutian Islands and along the southern coast, where zero readings have never been observed.

Lying, as it does, north of the Pacific Ocean, with the vast expanse of British America to the east, and separated only by Bering Strait from the larger land mass of Siberia to the west, the main portion of the Territory is covered during the winter by relatively high atmospheric pressure. Over the immediate water surface on the south there usually exists a trough of low pressure with a west-east trend, commonly known as the Aleutian LOW. Through this pressure valley, so to speak, pass a great many of the cyclonic disturbances of the Northern Hemisphere in their west-to-east movement. Other disturbances originate in it and altogether it exercises a great influence on the weather of the Territory as well as on that of the Canadian Provinces to the east and the northern half of the United States to the southeast.

The mountains of British Columbia, with their southeast-northwest trend, present somewhat of a barrier to the eastward movement of these barometric depressions, many of which stagnate in the Gulf of Alaska for days at a time, especially if the Pacific high-pressure area lying to the south manifests a tendency to move northeastward over Oregon and Washington. In fact, after reaching the Gulf of Alaska a cyclonic storm may be forced to pursue a retrograde movement and actually to move northwestward.

Whether from a breaking down of pressure in the Arctic slope of Alaska, or from the northward thrust of the Pacific High, these Aleutian LOWS occasionally take a northeastward movement over Bering Sea and advance toward Seward Peninsula and the Kobuk Valley of Alaska, or they may take a similar direction of movement farther east over the Yukon Valley. So long as the LOWS pursue their normal track over the north Pacific and the Gulf of Alaska, fair and cold weather obtains over the interior valleys of the Territory, with warm and rainy conditions over the southeastern panhandle. When, however, they take a northeastward movement, the temperature of the interior moderates under the influence of southerly winds, and precipitation to a greater or less

[1] Read before the meeting of the American Meteorological Society, Leland Stanford University, June 26, 1924.

extent ensues. Occasionally, from some cause, the Arctic High builds up to an exceptional extent, and then northerly winds, attended by fair and unusually cold weather, prevail over practically the entire Territory, including the usually warm and rainy south-southeastern section.

In the summer season, with the building up of pressure over the cooler waters of the north Pacific and the heating of the land surface of the interior under the influence of the long days of high latitudes, the interior pressure is relatively low and is attended by occasional rains.

With these meteorological conditions in mind as the major weather controls of the Territory, although modified greatly by its diversified relief, a few of the climatic features will be briefly considered. The southeastern or panhandle section will be taken up first.

It should be understood at the outset that this part of Alaska is of unusually strong relief. Mountainous in the extreme, the land areas are cut by innumerable tidewater bays, sounds, inlets, and fiords. Peaks 3,000 feet in height are common, while scores have elevations above 5,000 feet, and a number rise to 10,000 feet or more. Because of its strong relief and also because of its peculiar position with respect to the north Pacific storm track and its close proximity to the ocean itself, this southeastern portion of the Territory receives very heavy precipitation. In fact, at no observation station in the United States proper is the annual precipitation as great as is recorded at several stations at or near sea level in the Panhandle and Prince William Sound districts. Ketchikan, one of the most important commercial centers of the Territory, receives 157 inches annually, including the water equivalent of 40 inches of snowfall. Fortmann Hatchery, near by, receives 148 inches, and Cordova and Latouche, at the entrance of Prince William Sound, 131 and 147 inches, respectively. At Jumbo Mine, at an elevation of 1,500 feet, the total is about 193 inches a year, including approximately 450 inches of snowfall, as indicated by a three-year record.

The effect of increase of altitude on precipitation is indicated clearly in a comparison of the records of Juneau and Perseverance Camp. Although only 3 miles distant from each other, Juneau, at sea level, receives 80 inches a year, while Perseverance Camp, at 1,400 feet and in the lee of a precipitous and narrow mountain range 3,800 feet high and running athwart the moisture-laden southerly winds, receives about 150 inches. Juneau receives these same winds, but not the full effect of the adiabatic cooling incident to the ascent of the mountain. Clouds from which heavy rain is falling on the crest are perceived to continue their precipitation with apparently the same intensity for some distance in their horizontal movement across the valley in which Perseverance Camp is located.

Southeastern Alaska can lay claim to a heavier monthly precipitation than any on record in the United States, except for a few places in the mountains of California. Ketchikan had a total of 53.85 inches and Jumbo Mine, 61.46 inches, in November, 1917.[2]

Because of being so frequently in the eastern quadrant of the north Pacific cyclonic area, the frequency of precipitation also, exceeds that of any part of the United States. Whereas the rainiest portions of Washington, on the seaward slopes of the Olympics and Cascades, receive measurable precipitation on from 175 to 200 days a year, a large portion of southeastern Alaska has from 200 to 240 such days.

[2] In January, 1909, at Helen mine, California, 71.54 inches were recorded, and other points received more than 53.85 inches.

Despite the phenomenally large monthly and annual totals, there occur no intense downpours of short duration, such as are common in the central valleys of the States. This fact can be explained by the absence of convectional thunderstorms. At Juneau, with its annual precipitation of 80 inches and a maximum 24-hour fall of 5.54 inches, the maximum 15-minute fall is 0.28 inch, and the maximum hourly fall, 0.56 inch.

The economic importance of the heavy precipitation of southeastern Alaska may well be mentioned here. The extremely rugged topography of the country lends itself readily to the creation of storage reservoirs whereby the abundant precipitation can be utilized in the development of hydroelectric power. Already every town of importance is deriving light and power from this source, including a large gold-mining operation at Juneau, handling 8,000 tons of rock a day. Numerous other sites, some of them of large possibilities, have been surveyed and await the development of the vast timber and mineral resources with which the country is endowed.

However, it should not be inferred from the frequency and quantity of rainfall in the panhandle of Alaska that the air is always moisture laden, for, with a pressure distribution that induces northeasterly winds, blowing from the comparatively dry interior of British America, there comes a marked decrease in both the absolute and relative humidity, the latter being reduced still further by the adiabatic heating incident to the descent of the air from the mountain crests. A relative humidity of 12 per cent has been recorded at Juneau under such conditions. While these cases of extreme dryness are comparatively few, they nevertheless may create a forest fire-hazard in cut-over lands when they do occur, especially in the spring of the year, when the preceding year's growth of ferns and other vegetation has not yet been covered over and kept damp by the new growth.

As a corollary of the heavy precipitation may be mentioned the moderate temperatures that prevail in that region. At Juneau, with a January mean of 27° and a July mean of 57°, there is an average of only 108 days a year with freezing temperatures and at Sitka only 106, as against 186 days at Bismarck and 109 at Chicago. Zero readings occur less than twice a year at Juneau, on the average, and less than once a year at Sitka.

In the interior of the Territory, as exemplified by the great Yukon Valley, the outstanding features of the climate are the great annual range in temperature and the comparatively light precipitation. Separated from the Gulf of Alaska by the high mountain barriers of the Alaska range, the climate here, especially in the upper valley, is continental in the extreme. At Fort Yukon, on the Arctic Circle, the range between the January and July means is 89° and at Fairbanks, 76°, as against 71° at Pembina, N. Dak., which is generally considered as being one of the coldest places in the United States. The absolute range in temperature at Fort Yukon is 170°, at Fairbanks, 164°; and at Pembina, 155°.

The summer temperatures of the interior are delightfully pleasant, and, under the effect of the prolonged daylight, vegetation makes rapid growth. Temperatures of 70° and above occur on an average of only 13 days each summer in the lower Kuskokwim Valley, where the cooling influence of Bering Sea is manifest to some extent, but at Fairbanks the number of such days is increased to 61. In the Tanana and upper Yukon Valleys temperatures in excess of 90° are occasionally recorded. While freezing may occur in any of the summer months, except where there is good air drainage, such temperatures are usually of short duration and do little or no damage.

While the number of days a year with zero temperatures range from 61 in the Matanuska Valley to 123 at Fairbanks and 159 at Fort Yukon, such low readings do not persist throughout the winter, as is popularly supposed. That prolonged extreme cold may occur, however, is evidenced by the fact that in the winter of 1917–18 zero temperatures prevailed continuously in the upper Yukon Valley from November 23 to January 3, with a mean temperature for December at Eagle of −45.8° and a departure from the normal of −34.6°. At Dawson, Yukon Territory, the mean for December was −51.3°. Subnormal temperatures prevailed throughout the Territory during that month, except in the Aleutian region, under the influence of pressure that was half an inch above normal along the sixty-fifth parallel. In contrast to this abnormally cold December may be cited the same month three years previous, when the mean at Eagle was 7.8°, or 19.0 above normal, thus making a range in mean temperature for the month of 53.6°, as against a similar maximum range of the monthly means at Bismarck, N. Dak., of 33.6°.

The precipitation ranges from about 19 inches in the lower Yukon to about 12 inches in the middle Yukon and lower Tanana Valleys, but this shades off with recession from the sea until at Fort Yukon the total is less than 8 inches. The four months from June to September receive over half the year's precipitation—a condition most propitious for agriculture and placer mining. Thunderstorms are common during the summer months, but they are usually mild in character and are seldom attended by heavy hail.

As an illustration of the possibilities of agriculture in some of the interior valleys, it may be said that in the Fairbanks district, where spring wheat, oats, potatoes and other vegetables, and small fruits are successfully grown, there has been only one serious crop failure in the 19 years since farming was begun in that district. This was in 1922, when a killing frost on August 29 destroyed practically all crops. These had been unusually late in maturing because of a late spring and an unusually cloudy and wet summer.

The variability of the climate of the Territory from year to year is disclosed in a study of the records of five representative stations: Sitka and Fortmann Hatchery, in the southeast; Eagle and Fairbanks, in the interior; and Nome, on the northern Bering Sea coast. For the purpose of this study the calendar year was disregarded, and annual means were computed for the coldest and warmest periods of 12 consecutive months. Grouping the months in this way, it is found that at Eagle the coldest year had a mean that was 5.6° below normal, and the warmest year, 6.4° above. This does not differ materially from the record at Bismarck, where the maximum departures are −5.2° and +5.8°. The comparative uniformity of the coastal climate is exemplified by the Sitka record, which shows the coldest year to have been 2.4° below normal and the warmest, 3.7° above. At Seattle the maximum departures are −2.1° and +2.5°.

During the last 20 years, the calendar years 1905, 1912, 1914, 1915, and 1923 were decidedly above normal in temperature throughout the Territory from the Arctic Circle southward, while the years 1909, 1910, and 1917 were decidedly below normal. These departures from average temperatures are reflected in the records of Seattle, though in lesser degree, and, with two exceptions, at Bismarck.

The variability of precipitation from year to year likewise is greatest in the interior. Here, at Fairbanks and Eagle, with normals of approximately 10 and 12 inches, their wettest consecutive 12 months show excesses of 99 and 53 per cent, respectively, and the driest ones deficiencies of 39 and 37 per cent. At Nome, near the western extremity of continental Alaska, there has been an excess of 79 per cent and a deficiency of 58 per cent on an annual normal of 17 inches. At all three of these stations the precipitation is a factor in placer mining, and at Fairbanks in agriculture as well. The records at each station show the minimum 12-month totals to be sufficiently below the normal to interfere with, although not necessarily to suspend, operations along those lines.

In the southeastern portion of the Territory, as shown by the Fortmann Hatchery and Sitka records, the wettest 12-month periods were 28 per cent above the normal in quantity at both stations, although the normals differ by 64 inches, being 148 and 84 inches, respectively, for the period under consideration The driest 12-month periods show deficiencies of 28 per cent at Fortmann Hatchery and 29 per cent at Sitka. These figures show a probability of a fairly uniform supply of water for power purposes, although marked deficiencies for several consecutive months indicate the wisdom of providing storage facilities when practicable.

A comparison of these maximum and minimum departures from normal precipitation with similar data in the States shows the Alaskan climate in a favorable light. At Bismarck, with a typical continental climate, the excess of the wettest 12-month period is 87 per cent, and the deficiency of the driest, 55 per cent, with a normal of 17 inches. At Seattle, under considerable marine influence, the excess is 45 per cent and the deficiency 37 per cent, with a normal of 34 inches. Much greater departures from normal conditions than any of those enumerated above are found in the records of many stations on the Pacific slope, particularly in California.

In conclusion, it may be said that while the climate of Alaska presents great contrasts and in some sections is quite rigorous at times, it is healthful and invigorating. The economic development that has already taken place in the Territory has been achieved largely through the aid of climatic conditions, rather than in spite of them, as is sometimes contended. As an example, the overland transportation of supplies, machinery, etc., for mining and other development work, would be impossible in a climate with winter temperatures above freezing, without the building of expensive roads and bridges. Modern tractors now draw great loads across frozen streams, bogs, and tundra to remote districts, with but little previous preparation of roads and trails. The excessive precipitation of southeastern Alaska has fostered the development of the vast mineral and timber resources of that district by making available an abundance of cheap hydroelectric power. Even the great fur-seal industry of the Pribilof Islands is largely dependent for its success on the excessive amount of cloudy and foggy weather that prevails there during the seal-taking season, since the driving of the seals to slaughter can not be accomplished during periods of sunshine without an overheating of the animals and a lowering of the quality of the fur.

Given the necessary resources and favorable economic conditions, there is nothing in the climate of Alaska that should prevent the Territory from ultimately becoming a mighty empire among the States of the Union.

Extremes of mean temperature for periods of 12 consecutive months at representative Alaskan stations and at Seattle, Wash., and Bismarck, N. Dak.

Stations	Years of record	Normal	Coldest 12-month period			Warmest 12-month period		
			Date	Mean	Departure from normal	Date	Mean	Departure from normal
		°F.		°F.			°F.	
Eagle	17	23.8	July, 1917-June, 1918.	18.2	−5.6	October, 1914-September, 1915.	30.2	+6.4
Fairbanks	18	25.5	July, 1917-June, 1918.	21.1	−4.4	do	31.0	+5.5
Nome	17	25.2	January, 1920-December, 1920.	21.2	−4.0	January, 1912-December, 1912.	29.5	+4.3
Sitka	24	43.7	October, 1903-September, 1904.	41.3	−2.4	October, 1914-September, 1915.	47.4	+3.7
Fortmann Hatchery.	19	42.8	January, 1909-December, 1909.	38.9	−3.9	January, 1915-December, 1915.	46.6	+3.8
Seattle	32	51.3	January, 1916-December, 1916.	49.2	−2.1	January, 1892-December, 1892.	53.8	+2.5
Bismarck	49	40.5	December, 1874-November, 1875.	35.3	−5.2	December, 1877-November, 1878.	46.3	+5.8

Extremes of precipitation totals for periods of 12 consecutive months at representative Alaskan stations and at Seattle, Wash., and Bismarck, N. Dak.

Stations	Years of record	Normal	Wettest 12-month period			Driest 12-month period		
			Date	Total	Per cent of normal	Date	Total	Per cent of normal
		Ins.		Ins.			Ins.	
Eagle	17	9.87	July, 1910-June, 1911.	15.13	153	March, 1920-February, 1921.	6.22	63
Fairbanks.	18	11.88	November, 1906-October, 1907.	23.59	197	April, 1908-March, 1909.	7.28	61
Nome	17	17.37	December, 1921-November, 1922.	31.14	179	September, 1908-August, 1909.	7.33	42
Sitka	24	84.08	February, 1918-January, 1919.	107.58	128	October, 1902-September, 1903.	59.58	71
Fortmann Hatchery.	19	148.06	November, 1905-October, 1906.	188.88	128	June, 1919-May, 1920	107.05	72
Seattle	32	33.43	April, 1893-March, 1894.	48.39	145	December, 1910-November, 1911.	21.01	63
Bismarck	49	16.99	February, 1876-January, 1877.	31.78	187	June, 1889-July, 1890	7.70	45

ON THE APPLICATION OF THE FRONTAL THEORY TO CYCLONES IN THE SAHARA

By M. L. PETITJEAN

(Comptes Rendus, 179, No. 1, July 7, 1924, pp. 64-65)

[Translated by B. M. Varney, Weather Bureau]

The thermal discontinuity between winds of Mediterranean and of tropical origin in northern Africa reveals the existence, especially in the warmer months, of a special front,[1] which seems to be related to that of the Trade Winds.[2] It delimits the warm and the cold sectors of depressions, the centers of which, at the time of their appearance on the synoptic charts, occupy extreme sourthern Morocco, and the direction of movement of which is confined to either SW.–NE. or W.–E.

The warm sector is at first limited on its western side by the High Atlas of Morocco; it extends toward the north and follows in its course the Saharan chain of the Atlas. On the eastern side its boundary is prolonged as far as southern Tunis. The layer of southerly winds * * * extends to a higher altitude the greater is the heating in the tropical regions. It rises above the winds from the sea [these constituting the cold sector of the cyclone.—*Ed.*], and its progress northward can be traced from one station by the gradual lowering of its under side, as shown by pilot balloon soundings at military meteorological stations in Algeria and the Sahara.

While maintaining itself in general parallel to the orientation of the Atlas, the front of discontinuity oscillates, with variable amplitude and variable period, as a result of the conflict between the tropical and Mediterranean winds. This is made clear by tracing the lines of synchronous rainfall in connection with the stormy periods which accompany the passage of depressions originating in the Sahara. These lines give way, sometimes toward the north and sometimes toward the south, depending on whether the energy of the tropical winds or that of the winds from the sea is predominant. These alternating advances and retreats are the cause of a succession of very characteristic squalls. When the cold winds finally become dominant they gradually displace the layer of warm winds. Cloudiness decreases continuously and slowly, for the slope of the surface of discontinuity is very slight (a few mm. only), whereupon fine weather succeeds the stormy period.

The topography of north Africa influences the position of the surface of discontinuity as long as that surface passes above the crest of the Atlas Range, the tropical winds rise freely along it. But when, by reason of its shift in position, it is cut by the opposing slope, a foehn effect is produced which gives rise on the opposite side [north side] to a violent sirocco. After having expanded adiabatically during its ascent, the air finds itself after descent at a higher temperature as the result of adiabatic heating due to compression, this heating acting in addition to the gain of heat induced by condensation of water vapor during the ascent.

North of the Atlas the warm air is again forced up, this time above the ocean winds. This double ascent is revealed by the isochrones of rain occurring on the two sides of the mountainous massif.

The warm sector of Saharan depressions usually remains open toward the south side, but it may, as is the case with depressions in the Temperate Zone, be "cut off," either as a result of the arrival of colder air at its rear or of the weakening of the tropical flow. A second depression is thus produced following the first and may in its turn be cut off. It is not rare to discover on the charts of the meteorological service of Algeria cyclone families made up of three of these depressions in a string, lying essentially parallel to the trend of the Atlas.

[1] Petitjean, L., Surfaces de discontinuité en Algerie et au Sahara. (Cahiers du Service Météorologique d'Algerie, 1923, No. 1, p. 13.)

[2] Bjerknes, V., On the dynamics of the circular vortex, with applications to the atmosphere and atmospheric vortex and wave motions. (Geofysiske Publikationer Kristiania, 2, No. 4, 1921, pp. 62-63.)

SECONDARY DEPRESSIONS IN THE ADRIATIC SEA

By FILIPPO EREDIA

(Comptes Rendus, 179, No. 1, July 7, 1924, pp. 65, 67)

[Translated by B. M. Varney, Weather Bureau]

Sometimes, over the Adriatic appear barometric depressions which, as soon as they are formed, move rapidly in a direction from Northeast to southwest, gradually changing their course by turning toward the south when they reach Sicily or Tripoli. Rarely do they take a course toward the southeast, crossing the Ionian Sea to the Cyrenian Sea. These depressions, believed by most scientists to originate over the Tyrrhenian Sea, present very different characters from those of other depressions in the Mediterranean Basin.

The inception of these depressions is due to special conditions on the Adriatic slope. We may affirm these conditions to be, very limited thermal differences in comparison with those of adjoining regions, followed by decreases in pressure. In this case, under the influence of important depressions existing over northern Europe, there form on the Adriatic depressions which one may consider as secondaries.

If an anticyclone is present at the same time in north or northwest Europe, the depression develops more deeply and forms a growing cyclone. The gradients increased almost equally in the various sectors, and, coincident with an extension of the area of the cyclone, the pressure decreases, and the cyclone moves toward the east, while the anticyclone likewise shows a movement, but toward more southern latitudes.

However, if the western anticyclone, which we may assume to be well developed, influences the movement of these secondary depressions, the other anticyclone, which exists over the Levant, exerts an influence which is not less important. We may regard this anticyclone as an indefinite one, because it does not represent in general more than a zone of relatively high pressure as compared with that of adjacent regions.

The two currents of air, the one cold, the other warm, which, according to the theory of Bjerknes, are necessary to the formation of a depression, may be engendered by these two anticyclones, which lie, the one in northwestern, the other in southeastern Europe. [Details of depression of December 20 and 21, 1923.]

These depressions form preferably during the winter months and are entirely lacking in summer, for the distribution of air temperature at that season facilitates their formation in the valley of the Po.

Thus, the conditions favorable to the formation of these secondary depressions would be the following: A very marked cyclone over northern Russia, and two areas of high pressure extending, the one over the British Isles, the other over the Levantine Sea [eastern Mediterranean]. The depressions, as soon as they are formed, move as a function of the movement which the anticyclones undergo. The anticyclone dominant in the Levantine Sea thus exercises the major influence.

NOTES ON THE WEST INDIAN HURRICANE OF OCTOBER 14–23, 1924

By CHARLES L. MITCHELL

[United States Weather Bureau, Washington, D. C.]

Recent reports indicate that the hurricane of October 14–23, 1924, was one of great intensity. Dr. José C. Millas, director, Observatorio Nacional, Habana, Cuba, writes: "I believe that this hurricane is one of the most severe ever experienced in our latitudes." Doctor Millas has forwarded a number of photographs clipped from El Mundo, Habana, taken in Los Arroyos and Arroyos de Mantua, Pinar del Rio Province, which suggest that the force of the wind was almost comparable to that in a tornado. The steel wireless tower at La Fe was blown down.

It is, indeed, fortunate that this hurricane passed over no land areas other than the extreme western end of Cuba and a very sparsely settled region in southern Florida. Full details of damage done by it have not been received from western Cuba. Press reports indicate that in Arroyos de Mantua about a dozen persons were killed and 50 injured and that almost every building in the town sustained heavy damage, besides the severe damage done to the tobacco crop. A maximum wind velocity of 72 miles an hour from the south was registered at Habana at 10 p. m. of the 19th, although the barometer fell little, if any, below 29.50 inches. The lowest pressures observed at a number of stations in western Cuba and also very complete barometric data from the S. S. *Toledo*, all kindly furnished by Dr. Millas, are given below:

CUBAN STATIONS, OCTOBER 19, 1924

	Inches
Guane	28.97
Dimas	28.54
La Fe	28.35
Pinar del Rio	29.28
Mantua	28.15
Los Arroyos	27.52

S. S. "TOLEDO" NEAR JUTIAS CAY (OFF THE NORTHWESTERN COAST)

Time, Oct. 19	Wind direction	Wind force	Pressure
			Inches
Noon	E. by N	11	29.18
1:00 p. m.	E. by N	12	28.78
2:00 p. m.	East		
	ESE	12	28.06
2:10 p. m.	ESE	12	27.87
2:15 p. m.	ESE	12	27.72
2:25 p. m.	ESE	12	27.59
2:33 p. m.	ESE	12	27.48
2:40 p. m.	SE	12	27.44
2:50 p. m.	SE	12	27.36
3:00 p. m.	SE	12	27.28
3:15 p. m.	SE	12	27.26
3:30 p. m.	SSW	6	27.22
	WSW	8	
3:55 p. m.	SSW	12	27.26
4:10 p. m.	WSW	12	27.28
4:20 p. m.	West	12	27.40
4:30 p. m.	WNW	12	27.52
4:50 p. m.	WNW	12	27.87
5:00 p. m.	WNW	12	28.11
5:20 p. m.	WNW	12	28.39
5:30 p. m.	WNW	12	28.54
6:00 p. m.	WNW	12	28.80
7:00 p. m.	WNW	12	29.11
7:30 p. m.	WNW	11	29.19
8:00 p. m.	WNW	11	29.25
9:00 p. m.	WNW	11	29.33

The following extracts are from a report of an interview that the meteorologist of the Panama Canal Zone had with Captain Burmeister, master of the United Fruit Steam Ship *Heredia*:

* * * At about 7 p. m. (October 18) all three ships (the *San Bruno*, *Turrialba*, and *Heredia*) left Havana Harbor and preceded toward Cape San Antonio. At first there was practically no wind, but as they steamed west the wind went around to east and northeast and gradually freshened up. There was a fairly heavy following sea. The wind gradually became heavier and the sea higher. At about 3 a. m. (October 19) the master of the *San Bruno* * * * decided that the center (of the storm) was to the westward and he radioed the other ships that he was going to turn around and steam toward the northeast. After debating at some length, Captain Burmeister also decided to turn around. At this time the ships position was about 23° 50′ N. and 84° 10′ W. The ship was headed north-northeast for a while and then north. The pressure dropped steadily. At 4 a. m. the barometer read 29.56 inches and the wind northeast force 4. At 6 a. m. the sea was so high that the captain decided to heave to. A message to that effect was sent to the two other ships. At 8 a. m. the pressure was 29.44 and the wind had risen to northeast 8. The ship was empty and it bobbed around like a cork. At 11 a. m. the pressure was 29.15 and the wind northeast 11. * * * At noon the barometer read 28.10 inches. This was a drop of 1.05 inches in one hour. At that hour the wind was blowing from the northeast force 12. The following is a vivid description of the storm at its height by Captain Burmeister:

"The whole sea was a boiling, seething mass. It was impossible to see any distance. It appeared as if the surface were covered with a mass of turbulent steam. The sea was breaking in such manner that it was impossible to tell whether the water in the air was rain or sea water. I estimated the wind to be blowing 120 m. p. h. I ordered every pound of steam to be used in keeping her under control."

There was water in the staterooms and even in the captain's room on the bridge. The following note was written in the log at about this time:

"Hurricane winds with high seas. Ship laboring heavily. Taking heavy seas over forward and after decks."

The pressure dropped to its lowest point at 1 p. m., 28.05 inches (a test of this barometer at 28 inches showed that it was reading too high by 0.20 inch, making the corrected reading 27.85 inches). From 11 a. m. to 2 p. m. the wind blew with hurricane force, and waves were mountainous. After 1 p. m. the pressure rose quickly and by 4 p. m. it was 29.20. At 5 p. m. there was noted a backing of the wind, although the velocity was still high, north-northeast 10. As the wind continued to back the velocity decreased. By midnight the pressure had risen to 29.55 and the wind blew from the northwest with a force of 6.

The following is quoted from the report of the official in charge of the Weather Bureau office at Key West:

The storm's center at its nearest approach to Key West was 90 miles distant. This was about noon of the 20th, when the center bore northwest.

Notwithstanding the strong and consistently increasing winds which began during the night of the 19th and which culminated at 2 p. m. of the 20th with a maximum velocity of 66 miles an hour from the southwest, this storm caused no damage in Key West aside from some little damage to trees and shrubbery. There was no damage to shipping whatsoever. This was unusual in the face of a wind that for 17 hours maintained a velocity averaging 51 miles an hour, with gusts ranging from 54 to 74 miles an hour, and can be ascribed only to timely and persistent warnings issued by the Weather Bureau. Taking advantage of these warnings, all vessels, large and small, were made secure, windows and doors battened, and in a number of cases trees trimmed in order to lessen the wind effect and possibly save them.

As a result of warnings broadcast by radio, several vessels sought refuge in port. All P. & O. steamers were held on advice from this office. The following vessels were held in port pending the passage of the storm: Steamers *W. F. Burdell, J. R. Gordon, Roanoke, Estrada Palma, Henry M. Flagler, Joseph R. Parrott, Miami, William Islam,* and *Governor Cobb,* and the schooner *Mary Thompson.*

The bureau's work on this hurricane has called forth much praise from outside sources.

NOTES, ABSTRACTS, AND REVIEWS

WETTERVORHERSAGE (WEATHER FORECASTING)[1]

This volume is No. XI in the series of natural science publications brought out by Dr. Raphael Ed. Leisegang, Frankfurt-am-Main. The author, Doctor Georgii, is instructor in meteorology in the University of Frankfurt and has written a number of papers on meteorological subjects, especially within the last few years.

After sketching in Chapter I the development of weather forecasting since the time of Dove and indicating the synoptic weather reports available to European forecasters, together with the means of collecting and charting them, the author proceeds, in Chapter II—The dependence of the weather on pressure formations and air streams induced thereby—to discuss the problems of weather forecasting from synoptic weather charts. His method of developing the subject is quite naturally that of an instructor in meteorology.

He begins with the fundamental concepts of air movement as dependent upon the pressure distribution with such modifications as are introduced by surface friction, the rotation of the earth on its axis, and other influences, and these are clearly developed with the help of mathematical formulae, diagrams, and weather charts, the latter rather highly idealized with relation to air streams.

Very early in the discussion the results put forward by the Bjerknes school of meteorologists are considered and discussed, the author finding supporting evidence and illustrations in kite flights made in continental Europe. This discussion naturally leads to a consideration of the theories of origin of cyclones and anticyclones. A very full exposition of the Bjerknes wave theory is given and also of Exner's so-called drop theory. Since the latter is perhaps not well known to readers of the REVIEW in this country a brief abstract is given in the following paragraphs.

According to Exner, in the original stationary condition the isotherms and the isobars run parallel to each other. North of the line of discontinuity pressure is relatively high; south thereof relatively low. Normally polar air masses have an east-west movement. These winds, however, meet obstacles to their free and unobstructed westward movement, as on the east Greenland coast, Spitzbergen, and elsewhere in high latitudes. The winds are then deflected toward the south by the configuration of the earth's surface.

Since these masses of cold air by reason of their greater density are associated with higher pressure, the isobars in accordance with the deflection of the winds become curved toward the south. In the advanced stage the tongue of cold air forms more and more an inclosed center of high pressure with anticyclonic movement.

The warm west winds which here have been lifted from the ground by the cold air masses still blow (aloft) over the tongue of cold air and on its front side exerts a suction effect on the lower masses of warm air similar to that observed on the leeside of mountains on the passage thereover of the wind. As a result, this suction effect will produce on the front side of the tongue of cold air a dynamic pressure diminution which intensifies the already present low pressure thermally caused.

On the front side there are supplied to this cyclone thenceforth additional warm air masses. Thus, the cyclonic information acquires new energy through the intensifying of the temperature contrast.

Finally, the upper wind blowing over the tongue of cold, together with the movement of the lower cold and warm air masses resulting from the cyclonic formation, produce a migration toward the east. After the tongue of cold air has moved eastward of the point of invasion the earlier stationary condition gradually reestablishes itself until marked temperature contrasts have again developed, which produce a further sudden advance of cold.

In this way the inrushes of cold and the cyclonic formations become a periodic process which recurs at intervals at certain definite places on the earth.

Since the cold air masses disengage themselves droplike from the polar reservoir of cold, Exner's theory is called the "drop" theory of cyclones in contrast to Bjerknes wave theory.

The author makes the distinction that both the Bjerknes and the Exner theories explain the origin only of one group of cyclones, viz, that which is found in the lower levels—2 to 3 km. where the pressure differences are thermally produced.

It is not clear just how a distinction is to be made in actual forecasting between the influence of the two respective groups—those originating in the lower levels and those having their origin in the stratosphere.

The closing chapter on "long-range weather forecasting" brings forward little that is new or suggestive, perhaps for the very good reason that with the exception

[1] Wettervorhersage, W. Georgii, Dresden und Leipzig, 1924.

of the Indian meteorological service no other meteorological institution has developed a method of making dependable seasonal forecasts.

While the volume has been prepared with the needs of European forecasters in mind, it will be helpful to others as well, since many of the atmospheric processes described are of general occurrence, modified locally, of course, by the distribution of land and water and other peculiarities due to geographic factors.—*A. J. H.*

WEATHER ELEMENTS AFFECTING THE 1924 WINTER-WHEAT CROP IN ILLINOIS

The 1924 winter-wheat crop in Illinois was the poorest in average yield per acre since 1916. Insect pests were almost negligible, so it is inferred that the low yield in many counties was due to weather conditions. The percentage, by counties, of the 1924 yield per acre to the 14-year average shows that in general the yield was good north and west of the Illinois River. Very little winter wheat is grown in the northern counties, where the percentages are high. On the other hand, the percentages are low in one of the most important producing areas, the Illinois counties in the vicinity of St. Louis.

There were no adverse weather conditions prior to January, and wheat continued in good condition as a rule. January was a cold month. On the 5th the minimum temperature ranged from −4° to −25° at the extreme ends of the State, with little or no protection in the center and south, where the tops were frozen back. The temperature was less severe in the south. On the 21st it ranged from −11° to −24° throughout the northern division and much of the central, but with a general snow cover. The late-sown wheat was damaged by freezing and thawing during the latter half of February. May was unusually cold and cloudy, retarding the advance of vegetation. The winter's damage was progressively worse from north to south, there being considerable abandonment, and at harvest time the crop varied in condition from mostly good in the north to largely poor in the south.—*C. J. Root.*

CALIFORNIA FIRE SEASON CLOSED BY TIMELY RAINS

The most disastrous fire season that has occurred in California in a decade was closed this month by timely fall rains. Two years of markedly deficient rainfall was the outstanding factor which brought about this critical condition. The 1924 fire record surpassed, in number of fires and total area burned, that of 1917, a record fire year, also one of the driest seasons ever experienced in the State.

During the period January 1 to October 20 there were 2,439 forest, brush, and grain fires in California, which burned over 827,000 acres—an area greater than the State of Rhode Island—and caused an estimated loss of over $5,000,000 worth of natural resources and improved property. Thirty-two per cent of all fires were caused by lightning and 68 per cent were due to careless acts of man. Of the man-caused fires, 38 per cent were traced to smokers, largely users of "tailor-made" cigarettes, and campers were responsible for 13 per cent; incendiaries, 14 per cent; brush burners, 8 per cent; railroads, 6 per cent; lumbering operations, 4 per cent; and miscellaneous causes, 17 per cent.

Out of the total of 2,439 fires, 1,890 were within or adjacent to national forests and 549 were on State or private lands. Government land burned over amounted to 365,332 acres, or less than 2 per cent of the national forest area of the State. Private and State lands burned totaled 461,668 acres. The United States Forest Service spent $920,000 on fire suppression during the season.

Outstanding features of the 1924 fire season were: Four fire fighters killed on the fire line; the occurrence of over 100 large fires, ranging from 2,000 to more than 50,000 acres in area; the closure to public use of 10,000,000 acres of national forest land, and restrictions on camping and smoking placed on several million additional acres; the intensive state-wide educational campaign by the fire emergency organization sponsored by the Forest Service, State Board of Forestry, and the California Development Association, and the splendid backing given the fire-prevention movement by the press, organizations, and public-spirited citizens.—*United States Forest Service California District News Letter, October 31, 1924.*

THE EXTINGUISHING OF A FOREST FIRE BY SEA FOG

(Reprinted from Science Notes in Science, November 21, 1924)

A heavy dripping fog rolled in from the Pacific Ocean and put out effectively a fierce forest fire which had been burning for days in the Olympic peninsula southwest of Port Angeles, Wash. This is the only time recorded in northwest forestry of the occurrence of such a phenomenon. With no indication of rain and lacking water with which to fight the advance of the flaming menace, foresters watched the fire making progress toward the town of Quilcene, beyond which lay valuable tracts of big trees, when suddenly the wet fog descended. Like a huge gray cloud it settled down upon the forest, enshrouding everything. The fire fighters fled in terror lest they become bewildered and lost on the mountain sides. Soon the pungent smell of cedar and hemlock smoke disappeared and by mid afternoon, when the fog lifted, there remained but a few smoking dead logs, while all about the charred trunks of former merchantable trees dripped with water from the providential fire extinguisher.

WEATHER MAPS AT SEA

It may be interesting to recall the successive attempts that have led up to the preparation of daily synoptic weather maps on board ocean steamers.

As early as 1907 sporadic radio reports of meteorological observations made on ocean-going vessels were communicated to weather services on shore for use in weather forecasting, but the first organized effort to construct a daily synoptic weather chart at sea was the one conducted by Dr. P. Polis, director of the meteorological observatory of Aachen, Germany, on a voyage from Europe to the United States and return on the steamship *Kaiserin Auguste Victoria*, in August, 1908.[1]

It was not until after the war that the matter was revived, at which time the National Meteorological Service of France, cooperating with the Compagnie Générale Transatlantique, developed a system of collecting meteorological reports and preparing therefrom twice-daily synoptic weather charts on the steamship *Jacques Cartier*, Captain Chabot. These charts were based on reports from continental and oceanic areas and were unusually complete in scope and detail. The most

[1] Polis, P., Wireless telegraphy in the service of modern meteorology, MO. WEATHER REV., 36: 407, and Chart IX, August, 1908.

recent attempt in this direction and one made without any previous preparation was that of Messrs. Bjerknes and Giblett, representing the Norwegian and English meteorological services, respectively, on their voyage across the north Atlantic and return in connection with their attendance on the meeting of the British Association at Toronto in August, 1924. On the return voyage on the Cunard liner *Lancastria*, forecasts and weather information were broadcast about 4 p. m. daily.

The Weather Bureau has received from masters of vessels and others who received the forecasts words of hearty appreciation of the efforts of Messrs. Bjerknes and Giblett.—*A. J. H.*

George McCowen, 1833–1924

On October 6, 1924, at Ukiah, Calif., occurred the death of Dr. George McCowen. As a young man, Doctor McCowen came to California with his parents and settled in Mendocino County. During his lifetime he was a miner, blacksmith, farmer, surveyor, dentist, and student of meteorology. For 47 years he kept a record of precipitation; for 32 years and until the day of his death, he was cooperative observer for the Weather Bureau at Ukiah. In a letter to the San Francisco office of the bureau, under date of June 24, 1924, he wrote: "I have been reporting to your office since 1892; previous to that I kept private tally on the rainfall since 1877. But now I am beginning to cast about for a successor, having passed my ninety-first year." In another letter, dated July 9, 1924, Doctor McCowen wrote of his interest in the American Meteorological Society, but concluded with: "Feeling that I am near the end of life's journey, being in my ninety-second year, I do not care to invest." Doctor McCowen's services as cooperative observer were always of the highest quality and in his passing the Weather Bureau loses one of its most faithful friends, while his community loses its most respected and best-loved citizen.—*E. E. Eklund.*

BIBLIOGRAPHY

C. FITZHUGH TALMAN, Meteorologist in Charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies.

Angenheister, G.
Summary of the meteorological observations of the Samoa observatory (1890–1920) . . . Wellington. 1924. 56 p. diagr. plate. 24½ cm.

Bates, Carlos G.
Forest types in the central Rocky Mountains as affected by climate and soil. Washington. 1924. 152 p. figs. plates. 23½ cm. (U. S. Dept. agric. Dept. bull. no. 1233.)

Brooks, Charles F.
Why the weather? With the collaboration of John Nelson and others. New York. 1924. xvi, 310 p. front. illus. plates. 19½ cm.

Dorno, C.
. . . Lectures delivered on the occasion of the vacation course for medical men at Davos from August 19th to 26th, 1923. Brunswick. 1924. vi, 63 p. figs. 22½ cm. [General remarks on meteorology and climatology. Radiation. Medical climatology and high altitude climate.]

France. Bureau des longitudes.
Réception des signaux horaires, renseignements météorologiques, sismologiques, etc., transmis par les postes de télégraphie sans fil de la Tour Eiffel, Lyon, Bordeaux, etc. Paris. n. d. ix, 226 p. illus. plates (fold.). 24½ cm.

Gallé, P. H.
Klimatologie van den Indischen Oceaan. 'S. Gravenhage. 1924. 87 p. plates (fold.). 24½ cm. (K. Ned. met. inst., no. 102. Meded. en verh. 29a.)

Hamburg. Deutsche Seewarte.
Dampferhandbuch für den Stillen Ozean. Hamburg. 1922. xxiv, 624 p. illus. plates. 23½ cm.

Hellpach, Willy.
Die geopsychischen Erscheinungen. Wetter und Klima, Boden und Landschaft in ihrem Einfluss auf das Seelenleben. Dritte Auflage. Leipzig. 1923. xx, 530 p. figs. 24½ cm.

Kempen, J. F. A. E. van.
Rain observations, [on the] tobacco estate "Patik Radja" situated in . . . Banjoemas, Isle of Java, Dutch East Indies . . . Soerabaia. 1924. unp. illus. map. 22 cm. [Title and text in Dutch and English.]

Kobayasi, Tatuo.
Über die Mechanismen der Zyklonen and Antizyklonen. p. 189–212 figs. 26 cm. (Report Aeron. res. inst., Tôkyô imp. univ. no. 7, July, 1924.)

Langenbeck, R.
Physische Erdkunde. no. 2. Die Lufthülle und Wasserhülle der Erde. Berlin. 1923. 136 p. figs. 16 cm. (Sammlung Göschen.)

Lillo, Miguel.
Cuarenta años de observaciones pluviométricas y termometricas en la ciudad de Tucumán (1883–1923). Buenos Aires. 1924. 31 p. diagr. 26 cm.

Mangels, H.
Paraguay. Wirtschaftliche, naturgeschichtliche und klimatologische Abhandlungen. 2te Auflage. München. 1919. 255 p. plates. 23½ cm.

Marston, Frank A.
Distribution of intense rainfall and some other factors in the design of storm-water drains. p. 19–46. figs. plate (fold.). 23 cm. (Amer. soc. civil eng., Proceedings, Jan., 1924.)

Mexico. Secretaria de agricultura y fomento.
Atlas termopluviometrico de la Republica Mexicana, presentado al Congreso internacional de investigaciones cientificas. Reunido en Madrid en Octobre de 1924. Tacubaya. 1924. unp. plates. 28 cm.

Passarge, Siegfried.
Landschaft und Kulturentwicklung in unseren Klimabreiten. Hamburg. 1922. iv, 165 p. plates. 25½ cm.

Riel, P. M. van.
De stoomwegen van Ceylon naar de Golf van Aden in den Zuidwestmoesson. 'S. Gravenhage. 1924. 20 p. illus. 24½ cm. (K. Ned. met. inst., no. 102. Meded. en verh. 28.)

Sapper, Karl.
Die Tropen. Natur und Mensch zwischen den Wendekreisen. Stuttgart. 1923. xii, 152 p. 22 cm.

Sarasola, Simón.
Noticia del nuevo observatorio con algunos datos sobre la climatologia y el magnetismo de Colombia. Bogota. 1924. 84, iii p. illus. plates (fold.). 30½ cm. (Notas geofisicas y meteorológicas. no. 1.)

Shinn, W. C., mfg. co.
Shinn system of lightning prevention. Chicago. [c 1918.] 85 p. illus. 27½ cm.

Souleyre, A.
Les oscillations océaniques et les oscillations climatiques dans le passé et dans le présent. Le rythme de contraction du soleil. Bone. 1923. xix, 383 p. 24½ cm.

U. S. Signal corps. Meteorological section.
Cloud formations. [Washington. 1924?] 31 p. plates. 23½ cm. (Unit operations no. 6. Supplement.)

Vegard, L.
Light emitted from solid nitrogen when bombarded with cathode rays, and its bearing on the auroral spectrum. 14 p. figs. plate. 26½ cm. (K. Akad. van wetenschappen, Amsterdam.) (Repr.: Proceedings, v. 27, no. 1–2.)

Wieleitner, H[einrich Karl].
Schnee und Eis der Erde. Zweite Auflage. Leipzig 1920. 198 p. illus. plates. 15½ cm. (Bücher der Naturwissenschaft, hrsg. von S. Günther. 16. Bd.)

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY

The following titles have been selected from the contents of the periodicals and serials recently received in the library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

American journal of science. New Haven. (5) v. 8. October, 1924.

Visher, S. S. Sun spots and the frequency of tropical cyclones. p. 312–316.

American mercury. N. Y. v. 3. November, 1924.

Talman, Charles Fitzhugh. The new outlook in weather forecasting. p. 333–335.

American meteorological society. Bulletin. Worcester, Mass. v. 5. 1924.

Blake, Dean. Anticyclonic weather in California. p. 127–128. (Aug.–Sept.) [Abstract.]

Giblett, M. A., Richardson, L. F., & Whipple, F. J. W. Meteorological observations while crossing the Atlantic from England. p. 121–122. (Aug.–Sept.) [Abstract.]

Gregory, J. W. Inter-racial problems and white colonization in the tropics. p. 113–118. (Aug.–Sept.)

Kincer, J. B. The adjustment of agriculture to climate. p. 123–125. (Aug.–Sept.) [Abstract.]

McLennan, J. C. Recent developments in low temperature research. p. 120–121. (Aug.–Sept.) [Abstract. Deals with Vegard's studies of the aurora.]

Shaw, Sir [William] Napier. If the earth went dry. p. 119–120. (Aug.–Sept.) [Abstract.]

Stupart, Sir Frederic. The variableness of Canadian winters. p. 120. (Aug.–Sept.) [Abstract.]

Wells, Edward L. The climate of Portland, Oregon. p. 126. (Aug.–Sept.) [Abstract.]

Whipple, F. J. W. An experiment illustrating the theory of the green flash. p. 119. (Aug.–Sept.) [Abstract.]

Alps, H. F. Seasonal densities and storage of snowfall. p. 147. (Oct.) [Abstract.]

Bjerknes, J. The importance of atmospheric discontinuities for practical and theoretical weather forecasting. p. 148–149. (Oct.) [Abstract.]

Cornish, Vaughan. Wind, wave, and swell on the North Atlantic Ocean. p. 151–152. (Oct.) [Abstract.]

Grant, Robert Q. Some climatic features of Arizona. p. 146–147. (Oct.) [Abstract.]

Humphreys, W. J. The relation of wind to height. p. 148. (Oct.) [Abstract.]

Kimball, H. H. The determination of daylight intensity from automatic records of total solar and sky radiation. p. 150. (Oct.) [Abstract.]

McEwen, George F. Forecasting seasonal rainfall from ocean temperatures. Indications for the 1924–1925 season in Southern California. p. 137–139. (Oct.)

Marvin, C. F. Let us simplify the calendar and publish statistical data in standardized summaries. p. 150–151. (Oct.) [Abstract.]

Owens, J. S. The automatic measurement of atmospheric pollution. p. 149. (Oct.) [Abstract.]

Patterson, J. Upper air observations in Canada. p. 149–150. (Oct.) [Abstract.]

Richardson, L. F. Turbulence and temperature-gradient among trees. p. 149. (Oct.) [Abstract.]

Weeks, John R. The year without a summer, 1816, and the warm winter of 1815–1816. p. 140–141. (Oct.)

Whipple, F. J. W. The diurnal variation of pressure: facts and theories. p. 148. (Oct.) [Abstract.]

American society of heating and ventilating engineers. Journal. New York. v. 30. November, 1924.

Drinker, Philip, & Thompson, Robert M. The use of Owens' jet dust counter and of electric precipitation in the determination of dust, fumes, and smokes in air. p. 695–710.

Annalen der Hydrographie und maritimen Meteorologie. Berlin. 25. Jahrgang. Juli 1924.

Georgii, Walter. Korrelationen der Sommertemperatur in Mitteleuropa mit den Luftdruckverhältnissen voraufgehender Jahreszeiten in Süd- und Nordamerika. p. 166–168.

Astronomical society of the Pacific. Publication. San Francisco. v. 36. October, 1924.

Lewis, E. P. The spectrum of the aurora and of the night sky. p. 282–286.

Astronomie. Paris. 38. an. Septembre, 1924.

Mémeory, Henri. À propos du changement de temps le 15 août. p. 385–387.

Ecology. Brooklyn. v. 5. October, 1924.

Robertson, Charles. Phenology of entomophilous flowers. p. 393–407.

Thone, Frank. Rainproofing valves for atmometers: a résumé. p. 408–414.

Egatea. Porto Alegre. v. 9. 1924.

Pauwels, P. G. J. Subsidios para uma climatologia do Rio Grande do Sul. p. 212–214 (Maio e junho); p. 313–329 (julho e agosto); p. 419–422 (setembro e outubro).

Engineering news-record. New York. v. 93. 1924.

Hill, C. S. Winter construction as the contractor regards it. 1. Labor and climate. Storm and frost make winter work more difficult, but eagerness for employment raises the efficiency of the workmen. p. 532–535. (Oct. 2.)

Snow removal on Fall River road across Continental Divide. Month required to open highway—hand shovelers dig trench 6 ft. wide over 12-mile stretch—maximum depth of snow 19 ft. p. 550–551. (Oct. 2.)

Brockway, P. I. Floods and flood protection projects at Wichita. Three streams in city complicate problem—four floods and numerous overflows in semi-arid region, channel improvements and dikes; bridges to be rebuilt and raised—rainfall records. p. 828–832. (Nov. 20.)

France. Académie des sciences. Comptes rendus. Paris. t. 179. 1924.

Galissot, Ch. Dispositif simple permettant l'observation des troubles optiques de l'atmosphère; application à l'estimation de la définition des images données par les instruments. p. 459–461. (1 sept.)

Antoniadi, E.-M. Sur la décroissance retardée des neiges australes de Mars et sa coincidence avec le minimum solaire. p. 557–559. (22 sept.)

Mathias, E. Retour sur la théorie de l'éclair fulgurant. p. 550–553. (22 sept.)

Villard, P. Sur les expériences de la Courtine. p. 617–620. (6 oct.)

Geografiska annaler. Stockholm. Årg. 6, H. 2. 1924.

Lindholm, F. Les systèmes nuageux et la prévision du temps en France. p. 190–196.

Rossby, C.-G. On the origin of travelling discontinuties in the atmosphere. p. 180–189.

Wallén, Axel. La mesure de la grandeur de l'évaporation des lacs. p. 196–198.

Geographical review. New York. v. 14. October, 1924.

Allix, André. Avalanches. p. 519–560.

Reid, Harry Fielding. Antarctic glaciers. p. 603–614.

Hemel en dampkring. Den Haag. 22 jaarg. October 1924.

Gallé, P. H. Regenval te Amsterdam. p. 308–310.

Pfeiffer, Ir. J. C. Iets over opstelling en behandeling van instrumenten van amateur-meteorologen. p. 298–302.

India. Meteorological department. Memoirs. Calcutta. v. 23, pt. 8. 1924.

Walker, Sir Gilbert T. Frequency of heavy rain in India.

Marine observer. London. v. 1. November 1924.

Keeton, H. South Pacific hurricanes. p. 143–145.

Slide-scale for correcting the readings of mercurial barometers. p. 145.

Meteorologia pratica. Montecassino. Anno 2. Luglio-agosto 1924.

Eredia, F. La previsione della siccità. p. 145–148.

Meteorological magazine. London. v. 59. September 1924.

Brooks, C. E. The wet weather of April to August, 1924. p. 178–182.

G[iblett], M. A. British association for the advancement of science. Meeting in Toronto, August 1924. p. 173–178. [Reports meteorological features.]

The Kew pattern barometer—marine type. p. 192–193.

A new rain measure. p. 193–195.

S., G. C. Dr. A. Crichton Mitchell. p. 186–187.

Meteorologische Zeitschrift. Braunschweig. Bd. 41. Oktober 1924.

Bartels, J. Zur Korrelation März–September. p. 316–317.

Becker, E. Neuerung an Aneroidbarometern und Aneroidbarographen. p. 306–309.

Conrad, V. Der Expektanzbegriff von Arthur Schuster. p. 299–306.

Funk, S. Beobachtung einer Wolkentrombe. p. 320–321.

Kassner, C. Beithermometer. p. 320. [Proposed name for attached thermometer.]

Kerner, Fritz v. Die methodischen Fehler in der Paläoklimatologie. p. 293–298.

Kühl, W. Rechenschieber zur Berechnung der Luftfeuchtigkeit. p. 319–320.

Markgraf, Hans. Ein luftelektrischen Beitrag zur Zyklonentheorie. p. 314–316.

Meteorologische Zeitschrift—Continued.

Markgraf, Hans. Ueber die Berücksichtigung von luftelektrischen Störungen bei Mittelbildungen. p. 313–314.

Perlewitz, P. Windbeobachtungen über dem nördlichen und südlichen Atlantischen Ozean bis 22 km Höhe. p. 317–318.

Robitzsch, Max. Ein Feuchteschieber. p. 318–319.

Wegner, Rudolf. Eis- und Sommertage Deutschlands. p. 309–313.

Nature. London. v. 14. 1924.

Banerji, S. K. Microseisms associated with the incidence of the south-west monsoon. p. 576. (Oct. 18.)

Grant, Kerr. Potential gradient and atmospheric pollution. p. 576. (Oct. 18.)

Clark, J. Edmund, Margary, Ivan D., & Marshall, Richard. International cooperation in phenological research. p. 607–608. (Oct. 25.)

Hopkins, A. D. Notes on the bioclimatic law. p. 608–609. (Oct. 25.)

Dixey, F. Lake level in relation to rainfall and sunspots. p. 659–661. (Nov. 1.)

The International union of geodesy and geophysics. p. 697. (Nov. 8.) [Report of Madrid meeting.]

Mallock, A. Wind and waves. p. 679–680. (Nov. 8.)

Shaw, Sir Napier. If the earth went dry. p. 684–687. (Nov. 8.)

Nature. Paris. 52 année. 8 novembre 1924.

Bureau, Robert. Les "atmosphériques" de la T. S. F. Leurs propriétés météorologiques. p. 301–303.

Rudaux, L. L'ouragan du 8 octobre. p. 303–304.

Naturwissenschaften. Berlin. 12. Jahrg. 26. September 1924.

Brinkmann, R. Ueber Eiszeittheorien. p. 800–806.

Philosophical magazine. London. v. 48. November 1924.

Morton, W. B., & Woods, Amy I. On air-waves of finite amplitude. p. 866–883.

Physikalische Zeitschrift. Leipzig. 25. Jahrgang, no. 18. 1924.

Holtzmann, Mark. Eine neue Methode zur Bestimmung der Temperatur des Taupunktes, p. 443–445.

Wigand, A. Die durchdringende Höhenstrahlung. p. 445–463. [Summary of existing knowledge, with bibliography.]

Popular astronomy. Northfield, Minn. v. 32. November 1924.

King, Edward S. Spectrograms of sky polarization. p. 553. [Abstract.]

Revue générale des sciences. Paris. 32. an. 30 octobre 1924.

Sayles, Robert W. Les problèmes de la paléoclimatologie. p. 573–581.

Royal meteorological society. Quarterly journal. London. v. 50. July 1924.

Blackman, V. H. Atmospheric electric currents, normal and abnormal, and their relation to the growth of plants. p. 197–207.

Royal meteorological society—Continued.

Brownlee, John. Ultra-violet radiation and cooling power of the air. p. 252–254.

Chapman, S. The semidiurnal oscillation of the atmosphere. p. 165–195.

Chree, Charles. On the diurnal variation of atmospheric pressure at Eskdalemuir and Castle O'er, Dumfriesshire. p. 245–247.

Giblett, M. A. The international free-balloon race for the Gordon Bennett cup. p. 260–267.

Hill, Robin. A lens for whole sky photographs. p. 227–235.

Margary, Ivan D. Glaisher stand *versus* Stevenson screen. A comparison of forty years' observations of maximum temperature, as recorded in both screens at Camden Square, London. p. 209–226.

Mr. Richard Strachan. p. 272–273. [Obituary.]

Penetrating radiation in the upper air. p. 243–244.

Professor C. A. Angot. p. 270–271. [Obituary.]

Professorship of meteorology at the Imperial college of science and technology; retirement of Sir Napier Shaw. p. 259–260.

Russell, Spencer C. Daily well measurements during 1923 at Chilgrove, Sussex, and Detling, Kent. p. 248–249.

Sir Gilbert Walker. p. 244.

Whipple, F. J. W. The significance of regression equations in the analysis of upper air observations. p. 237–243.

Winter thunderstorms. p. 258–259.

Whitcomb, S. F. The heavy floods of May 31st and June 1st, 1924. p. 254–257.

Royal society of London. Proceedings. London. ser. A. v. 106. October, 1924.

Atkinson, R. d'E. Note on Vegard's theory of the aurora. p. 429–440.

Science. New York. v. 60. 1924.

Anslow, Gladys. The total ionization produced in air by electrons of various energies. p. 432–433. (Nov. 7.)

Dall, Wm. H. Thermometer scales. p. 454–455. (Nov. 14.)

Ozone. p. x. (Nov. 14.)

Smithsonian institution. Washington. Annual report. 1924.

Douglass, A. E. Some aspects of the use of the annual rings of trees in climatic study. p. 223–239.

Humphreys, W. J. Fogs and clouds. p. 187–221.

Società meteorologica italiana. Bollettino bimensuale. Torino. v. 44. Luglio–settembre 1924.

Marangoni, Carlo. Teoria vorticosa della grandine. p. 46–53.

Pesci, Giuseppe. Abbachi psicrometrici e barometrici. p. 53–56.

SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING OCTOBER, 1924

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January and February, 1924, **53**:42 and 113.

From Table 1 it is seen that solar radiation intensities on a horizontal surface averaged above normal at Washington, D. C., and Madison, Wis., and close to normal at Lincoln, Nebr. At Washington a radiation intensity of 1.51 gram-calories per minute per square centimeter of normal surface, measured at noon on October 13, exceeds any radiation intensity heretofore measured at that station in October, and equals the previous maximum intensity for the year, which was measured on April 5, 1918.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged above normal at the three stations for which normals have been determined.

Sky light polarization measurements made on nine days at Washington give a mean of 62 per cent, with a maximum of 68 per cent on the 2d. Measurements obtained on nine days at Madison give a mean of 62 per cent, with a maximum of 66 per cent on the 22d. The values for Washington are above and those for Madison are below the averages for October for the respective stations.

TABLE 1.—*Solar radiation intensities during October, 1924*

[Gram-calories per minute per square centimeter of normal surface]

Date	8 a.m. 75th mer. time	Sun's zenith distance 78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon Local mean solar time
		Air mass A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
Washington, D. C.											
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Oct. 1	4.75	0.87	1.01	.....	1.33	1.50	1.28	1.11	0.95	0.84	5.36
2	6.76	.....	.....	1.00	1.18	1.43	1.23	1.05	0.91	0.81	6.76
3	7.57	0.96	1.01	1.14	1.25	.....	1.08	.....	.....	.....	7.04
8	9.14	.....	.....	.....	.....	1.48	1.31	1.07	0.98	0.92	6.50
9	5.36	0.92	1.01	1.16	1.31	1.49	1.27	1.03	0.93	0.80	5.56
10	6.02	1.01	1.12	1.24	1.37	1.55	.....	.....	.....	.....	5.56
13	4.95	0.98	1.08	1.21	1.37	1.60	.....	.....	.....	.....	3.30
14	6.02	0.81	0.88	1.03	1.19	1.42	.....	.....	.....	.....	4.95
21	3.45	0.94	1.04	1.18	1.33	1.48	.....	.....	.....	.....	3.30
22	3.81	0.91	1.00	1.17	1.34	.....	.....	.....	.....	.....	3.30
23	4.17	.....	0.98	1.14	1.32	1.54	1.32	0.97	0.86	0.75	3.45
24	4.57	.....	0.76	0.91	1.09	.....	.....	.....	.....	.....	4.95
Means	.....	**0.92**	**0.99**	**1.12**	**1.28**	**1.50**	**1.25**	**1.05**	**0.93**	**0.82**	.....
Departures	.....	**+0.14**	**+0.14**	**+0.18**	**+0.17**	**+0.04**	**+0.14**	**+0.13**	**+0.14**	**+0.12**	.....
Madison, Wis.											
Oct. 1	4.57	.....	.....	0.93	1.14	1.38	1.07	.....	.....	.....	7.04
2	78.7	.....	.....	.....	1.04	.....	1.14	.....	.....	.....	9.83
17	7.57	.....	.....	.....	1.07	.....	.....	.....	.....	.....	9.14
21	4.57	1.03	1.11	1.22	1.33	1.47	1.33	.....	.....	.....	4.37
22	4.57	.....	1.05	1.18	1.33	1.53	1.33	1.05	.....	.....	4.37
23	3.45	.....	.....	.....	1.18	.....	.....	.....	.....	.....	4.37
27	3.99	.....	.....	.....	1.23	.....	1.18	.....	.....	.....	3.81
31	6.27	.....	.....	.....	1.32	.....	1.30	1.15	.....	.....	6.02
Means	.....	**(1.03)**	**(1.08)**	**1.11**	**1.20**	.....	**1.22**	**(1.10)**	.....	.....	.....
Departures	.....	**+0.31**	**+0.16**	**+0.05**	**+0.02**	.....	**+0.04**	**+0.08**	.....	.....	.....

* Extrapolated

TABLE 1.—*Solar radiation intensities during October, 1924*—Contd.

Date	8 a.m. 75th mer. time	Sun's zenith distance 78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon Local mean solar time
		Air mass A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
Lincoln, Nebr.											
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Oct. 1	6.27	0.87	1.00	1.14	1.31	1.51	.....	.....	.....	.....	6.76
2	6.76	.....	0.99	1.07	1.29	.....	0.91	.....	.....	.....	6.76
9	8.18	.....	.....	.....	.....	1.52	1.28	1.15	1.01	0.93	6.02
13	4.37	0.95	1.03	1.15	1.32	1.52	.....	.....	.....	.....	4.57
16	8.81	.....	0.54	0.69	0.99	.....	0.99	.....	.....	.....	9.83
23	2.62	.....	1.00	1.12	1.30	.....	1.26	1.09	0.94	0.79	3.45
24	3.30	0.83	0.95	1.08	1.20	1.35	.....	.....	.....	.....	3.63
31	3.45	0.79	0.91	1.28	1.39	.....	.....	1.12	0.95	.....	3.00
Means	.....	**0.86**	**0.92**	**1.08**	**1.26**	.....	**1.11**	**1.12**	**0.97**	**0.86**	.....
Departures	.....	**−0.04**	**−0.04**	**−0.03**	**−0.02**	.....	**−0.14**	**+0.04**	**+0.03**	**+0.03**	.....

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation Washington	Madison	Lincoln	Chicago	New York	Average daily departure from normal Washington	Madison	Lincoln
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Oct. 1	389	352	342	277	327	+61	+68	−11
8	415	267	306	251	357	+107	+12	−17
15	328	225	287	205	301	+41	−5	−5
22	276	266	321	208	266	+12	+60	+59
Excess or deficiency since first of year on Oct. 28, 1924						+1,301	−7,038	+2,850

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The following table shows the average sea-level pressure at a number of land stations on the coast and islands of the North Atlantic. The readings are for 8 a. m., 75th meridian time, and the departures are only approximate, as the normals were taken from the Pilot Chart and are based on Greenwich mean noon observations, which correspond to those taken at 7 a. m., 75th meridian time.

Station	Average pressure	Departure
	Inches	*Inches*
St. Johns, Newfoundland	29.82	−0.12
Nantucket	30.13	+0.11
Hatteras	30.17	+0.14
Key West	29.91	−0.07
New Orleans	30.10	+0.09
Swan Island	29.73	−0.18
Turks Island	29.95	0.00
Bermuda	30.08	+0.06
Horta, Azores	30.12	+0.01
Lerwick, Shetland Islands	29.78	0.00
Valencia, Ireland	29.82	−0.09
London	29.92	+0.02

It will be noticed from above table that while the departures were not especially large, they varied considerably. The unusually low pressure in the Caribbean Sea was due to the number of tropical disturbances that prevailed during the month. The barometric readings at Horta ranged from 29.64 inches on the 26th to 30.38 inches on the 1st, and at Lerwick from 29.14 inches on the 6th to 30.42 inches on the 14th.

Taking the ocean as a whole, the month was one of the stormiest Octobers on record. Tropical disturbances, described elsewhere in the REVIEW, were unusually frequent, one of them being exceptionally severe. In northern waters the number of days with winds of gale force was considerably in excess of the normal for the current month, and over the middle and eastern sections of the steamer lanes was fully equal to and in some localities greater than the normal for January, which is considered the most tempestuous month of the year.

The number of days in which fog was reported was considerably less than the normal over the Grand Banks and slightly above over the greater part of the steamer lanes and off the European coast; it was recorded on from 2 to 4 days along the American coast, north of the 35th parallel, and on 2 days in the Gulf of Mexico.

On the 1st the Icelandic LOW was unusually well developed, with a barometric reading of 28.50 inches at Seydisfjord, and moderate to strong gales over the region between the 35th meridian and the European coast. On the 2d there was a disturbance of limited extent near 30° N., 55° W., that traveled slowly northward, and on the 4th was central near 42° N., 50° W.; it then curved sharply eastward and on the 6th was about 5° north of the Azores. Four storm logs relating to this disturbance, covering the period from the 2d to 6th, will be found in Table 1.

On the 6th there was also a deep depression central about 10° west of the north coast of Scotland, with strong northerly gales in the western quadrants, as shown by storm log in table.

From the 8th to 10th a disturbance of limited extent moved slowly eastward over the northern steamer lanes,

reaching its greatest intensity on the 9th, near 52° N., 50° W., where northwest gales, force 10 were encountered.

From the 8th to the 11th northerly winds of gale force were reported at different points along the American coast, between Nova Scotia and Florida, accompanied for the most part by comparatively high barometric readings.

On the 12th there was a disturbance in the vicinity of Newfoundland that moved rapidly eastward, and on the 14th was central near 55° N., 23° W. On the 12th there was also a LOW in the Gulf of Mexico that was responsible for moderate easterly gales between the 25th and 30th parallels.

On the 15th there was a depression in the western part of the Caribbean Sea that afterwards developed into an exceptionally severe tropical disturbance that reached its greatest intensity on the 19th. This disturbance is described elsewhere in the REVIEW. Storm logs from vessels involved appear in the table below.

Charts VIII to XII cover the period from the 17th to 22d, inclusive. On the 19th there was a LOW over Newfoundland, as shown on Chart X; this moved slowly eastward, increasing in force, reaching its greatest intensity on the 22d, and was central on the 23d near 58° N., 25° W.

This disturbance was closely followed by a second that was over Newfoundland on the 24th, although at time of observation on that day no especially heavy winds were reported; it developed rapidly, however, in its eastward course, and on the 25th was central near 50° N., 35° W., with strong gales over the region between the 30th and 50th meridians. During the next 24 hours the easterly movement of this LOW was slight, as on the 26th the center was near 50° N., 30° W., and on the 27th about 10° west of the north coast of Ireland. On the 26th the storm area extended as far south as the Azores, while by the 27th it had contracted somewhat.

These two disturbances were closely followed by a third that on the 27th was central near 50° N., 47° W., with northerly gales in the western quadrants. Pursuing a more northerly course than its predecessors, this LOW on the 31st was off the north coast of Scotland. During its progress reports of gales were received from vessels over the greater part of the steamer lanes, the storm area at times extending as far south as the 35th parallel. (See Table of Ocean Gales and storms.)

TABLE OF OCEAN GALES AND STORMS, OCTOBER, 1924

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN								*Inches*					
American Press, Am. S. S.	Avonmouth	New Orleans	31°46′ N.	53°48′ W.	1st	7 a. m., 2d	2d	29.71	se.	se., 9	s.	se., 9	Steady se.
Boschdijk, Du. S. S.	New York	Rotterdam	41°48′ N.	51°25′ W.	3d	4 a. m., 4th	4th	29.63	ene.	ne., 9	nnw.	ne., 9	ene.-n.
Binnendijk, Du S. S.	Rotterdam	Philadelphia	45°27′ N.	42°31′ W.	5th	7 a. m., 5th	5th	29.76	sse.	nne., 10	nw.	nne., 10	ssw.-nne.
Duquesne, Am. S. S.	Manchester	New Orleans	44°20′ N.	25°50′ W.	6th	1 p. m., 6th	6th	29.49	s.	nw., 4	n.	n., 10	ssw.-nw.-n.
Eastern Star, Am. S. S.	Kotka, Finland	Boston	57°58′ N.	22°35′ W.	5th	10 p. m., 5th	7th	29.31	wsw.	w., 7	w.	nw., 10	sw.-w.-nw.-w.
Lackawanna, Br. S. S.	New York	Avonmouth	44°04′ N.	47°27′ W.	11th	8 p. m., 12th	13th	29.38	ese.	sw., 7	wsw.	s., 9	ssw.-sw.
Stockholm, Swed. S. S.	Gothenburg	New York	57°50′ N.	22°04′ W.	14th	8 p. m., 14th	15th	29.43	sw.	s.	w.	s., 9	s.-w.
La Marea, Br. M. S.	Central America	do	19°00′ N.	86°15′ W.	15th	6 a. m., 16th	18th	29.19	wnw.	nw., 7	ne.	ne., 10	nw.-n.-ne.
Knockfierna, Br. S. S.	Port Arthur	Panama	18°50′ N.	84°10′ W.	15th	4 p. m., 18th	19th	29.44	ene.	sse., 10	sw.	11	sse.-ssw.
Toco, Br. S. S.	Canal Zone	Port Arthur	20°27′ N.	85°07′ W.	18th	2 a. m., 19th	19th	28.18	se.	se., 8	w.	ne., 12	se.-ne.-nw.
Cockaponset, Am. S. S.	Antwerp	Galveston	25°27′ N.	79°23′ W.	20th	5 a. m., 21st	21st	29.36	sse.	sw., 10	wnw.	wsw., 11	sse.-wnw.
Mesaba, Br. S. S.	London	New York	42°30′ N.	55°06′ W.	19th	10 p. m., 19th	20th	29.38	wnw.	w., 9	wnw.	10	wnw.-nw.
Volendam, Du. S. S.	Rotterdam	do	45°46′ N.	41°45′ W.	20th	2 p. m., 20th	21st	29.08	wsw.	w., 8	wsw.	wsw., 9	
Nienburg, Germ. S. S.	Bremen	Philadelphia	48°29′ N.	29°32′ W.	22d	8 p. m., 22d	23d	29.30	sw.	s., 10	n.	s., 10	s.-w.-n.
Nortonian, Br. S. S.	Liverpool	Galveston	39°10′ N.	47°21′ W.	24th	10 p. m., 24th	25th	29.66	wnw.	wnw.	w.	wnw., 10	
Verentia, Br. S. S.	New York	London	47°30′ N.	32°00′ W.	24th	2 a. m., 26th	28th	28.35	sw.	sw.	sw.	sw., 10	s.-w.
Sinaia, Fr. S. S.	Marseille	New York	37°30′ N.	29°40′ W.	25th	4:30 p. m., 25th	28th	29.23	se.	nnw., 10	nnw.	nw., 11	se.-sw.-nw.
Anaconda, Am. S. S.	Rotterdam	do	46°14′ N.	44°02′ W.	27th	4 p. m., 27th	28th	29.50	wnw.	wnw., 7	wsw.	9	wnw.-wsw.
Sacandaga, Am. S. S.	Liverpool	Savannah	45°50′ N.	35°13′ W.	28th	8 p. m., 28th	29th	29.51	nw.	nw., 8	w.	9	nw.-w.
Dakarian, Br. S. S.	New York	English Channel.	50°15′ N.	1°15′ W.	29th	4 a. m., 30th	Nov. 1	29.53	wsw.	w., 8	w.	w., 8	Steady w.
NORTH PACIFIC OCEAN													
Reiyo Maru, Jap. S. S.	Karatsu, Japan	Vancouver	44°59′ N.	159°46′ E.	1st	4 p. m.	1st	29.81	sw. x w.	s.x w.,9	sw. x w.	s. x w., 9	s. to sw. x w.
Crosskeys, Am. S. S.	Kobe, Japan	Seattle	42°45′ N.	156°00′ E.	3d	10 a. m.	3d	29.87	n.	n., 7	nne.	nne., 9	nnw. to nne.
Siberia Maru, Jap. S. S.	Yokohama	Honolulu	32°27′ N.	170°47′ E.	4th	8 p. m., 5th	6th	29.81	n.	nnw., 8	ene.	nnw.-ene., 8	nnw.-n.-ene.
Achilles, Br. S. S.	do	Victoria	49°48′ N.	171°19′ W.	7th	1:37 a. m., 9th	9th	29.71	s.	ssw., 8	w.	ssw., 8	s. x e.-s.-sw.-w
Reiyo Maru, Jap. S. S.	Karatsu	Vancouver	49°06′ N.	163°54′ W.	8th	8 p. m.	8th	29.98	ssw.	ssw., 8	sw.	ssw., 8	s.x w.-ssw.-sw.
Anna E. Morse, Am. S. S.	Portland, Oreg.	Yokohama	47°18′ N.	166°15′ E.	9th	3:30 a. m.	9th	29.57	sse.	sse., 8	sw.	sse., 8	sse.-sw.-nw.
Yuri Maru, Jap. S. S.	Vancouver	Norfolk, Va.	46°30′ N.	126°06′ W.	13th	5 a. m., 15th	15th	29.26	e.	e., 9	sse.	e., 9	e.-sse.
Makura, Br. S. S.	Honolulu	Vancouver	38°10′ N.	142°10′ W.	13th	8 p. m., 14th	15th	29.69	wnw.	wnw., 8	nnw.	wnw-nnw., 8	wnw.-nnw.
Santa Cruz, Am. S. S.	do	Tacoma	40°30′ N.	137°55′ W.	14th	8 a. m., 14th	15th	29.40	nw.	nw., 6	nnw.	nw., 10	nw. steady.
Meton, Am. S. S.	Manila	San Francisco	34°53′ N.	152°30′ E.	14th	1:30 a. m., 16th	16th	29.88	ne.	ene., 7	ene.	ene., 8	Steady.
Do	do	do	44°15′ N.	170°58′ W.	22d	5 p. m., 22d	23d	29.82	nw.	nw., 8	nw.	nw., 8	nw., steady.
Hollywood, Am. S. S.	Borneo	do	40°40′ N.	161°15′ W.	22d	4 p. m., 22d	24th	29.65	wnw.	nw.	w.	nw., 10	nw., steady.
Makura, Br. S. S.	Victoria	Honolulu	46°08′ N.	129°24′ W.	23d	8 p. m., 23d	24th	29.45	s.	s., 8	sw.	s., 8	s.-sw.
Do	do	do	38°32′ N.	139°12′ W.	25th	5:30 p. m., 25th	26th	29.62	sw.	sw., 9	nw.	sw., 9	ssw.-sw.-wsw-wnw.
Shabonee, Br. S. S.	Nagasaki	San Pedro	43° N.	178° W.	25th	8 p. m., 25th	26th	29.65	sw.	wsw., 8	nw. x n.	wnw., 9	wsw.-wnw.
West Chopaka, Am. S. S.	Yokohama	San Francisco	36°28′ N.	179°48′ W.	27th	6 a. m., 28th	28th	29.61	ne.	ssw., 8	ssw.	sse., 9	sse.-ssw.
Meton, Am. S. S.	Manila	do	43°13′ N.	143°53′ W.	27th	11 a. m., 27th	28th	29.26	sw.	wsw., 8	nw.	nw., 9	wsw.-nw.
Celtic Prince, Br. S. S.	Honolulu	Yokohama	34°28′ N.	140°01′ E.	28th	3 p. m., 28th	29th	29.83	wnw.	sse., 7	----------	8	sse.-wnw.
Storviken, Nor. S. S.	Japan	Portland, Oreg.	48°11′ N.	135°11′ W.	28th	4 a. m., 28th	29th	28.81	wnw.	wnw., 8	w nw.	n., 11	w.-n.
President Jefferson, Am. S. S.	Yokohama	Seattle	42°07′ N.	157°35′ E.	28th	5:15 p.m., 29th	29th	29.43	s.	sse., 10	nw. x w.	sse., 10	s.-se.-nw. x w.
Hauraki, Br. S. S.	Vancouver	San Francisco	47°30′ N.	124°50′ W.	28th	7 p. m., 28th	30th	28.88	se.	se., 9	w.	se.-s., 9	----------
Hannawa, Am. S. S.	Yokohama	Portland	44°05′ N.	156°38′ E.	28th	10 p. m., 29th	29th	29.47	s.	s., 11	----------	s., 11	s. steady.
Meton, Am. S. S.	Manila	San Francisco	40°35′ N.	130°14′ W.	29th	2 a. m., 30th	30th	29.69	ssw.	ssw., 8	ssw.	ssw., 8	ssw. steady.
Hawaii Maru, Jap. S. S.	Yokohama	Victoria	48°23′ N.	172°11′ E.	28th	11 a. m., 31st	Nov. 1	29.48	se. x s.	e., 3	se. x e.	se. x e., 8	se.-e.-s.

NORTH PACIFIC OCEAN

By WILLIS EDWIN HURD

There was somewhat less cloudiness over the northern sailing routes of the North Pacific Ocean in October than during the previous several months. Fog also was comparatively infrequent, and was general only on the 2d, 3d, 4th, and 8th. It was observed on 15 days along the American coast between Vancouver and San Diego, with the area of maximum frequency lying between 35° and 40° N.

Little change was evident in the distribution of storminess over that of September, except that gales occurred more often in the American than in the Asiatic area, with the maximum frequency north of the thirtieth parallel along the general region of the Seattle-Honolulu route. No wind forces exceeding 10 were recorded until the last of the month, when two observations of force 11 were made in widely separated areas—one near 48° N., 135° W., on the 28th; the other near 44° N., 157° E., on the 29th. At this time also vessels reported some of the lowest pressures observed in the eastern North Pacific Ocean.

Pressure was abnormally high this month at the three island stations of the central and northern Pacific, which are usually taken as the basis of barometric conditions in their respective neighborhoods. Honolulu's mean of 30.05 inches, with departure from the normal of plus 0.05, was unusually high. At Midway Island the mean p. m. pressure was 30.07, or 0.06 inch above the normal. Here from the 8th to the 26th the departures were strongly positive. At Dutch Harbor observations received for 22 days gave a mean of 29.98, or 0.28 above the normal. There were some rapid and violent fluctuations, as on the 8th, when the pressure dropped to 0.46 inch below normal, and on the 10th, when it rose to 0.67 inch above. During the first 7 and last 4 or 5 days, however, pressure was continuously very high. At Honolulu the highest pressure was 30.18, on the 29th, lowest, 29.88, on the 4th; Midway Island, highest, 30.32, on the 19th, lowest, 29.78, on the 4th; Dutch Harbor, highest, 30.66, on the 5th, lowest, 29.00, on the 15th.

The Aleutian LOW was less well developed over southern Bering Sea than during September. After the 8th its principal center, as a rule, lay over the Gulf of Alaska. The lowest land pressure in this region was 28.82, at Kodiak, on the 15th. On the 27th the cyclone center moved considerably southward and for the remainder of the month lay slightly off or over Vancouver. At Juneau the October pressure was 29.64 inches. This reading on the northeast edge of the cyclone showed a departure from the average of −0.23 inch.

The easternmost north Pacific anticyclone was strong and well developed until the 14th, when it was bisected by a southward spread of the Gulf of Alaska cyclone. The HIGH regained its lost area during the 15th, but was again cut in two on the 17th, and by the 20th low pressure was general over the extreme eastern part of the ocean. The HIGH continued as a shallow, irregular belt below latitude 30° or 35° until near the end of the month, when it strengthened and spread northwestward and extended from southern California across the Hawaiian region, thence into Bering Sea.

The weather at Honolulu was windy and cloudy. The average wind velocity, 9.9 miles per hour, was the highest on record for October; and the maximum velocity, at the rate of 33 miles an hour from the east, was next to the record for the month. Only one previous October, that of 1916, had less sunshine.

In the American tropical area there seems to have been no storm development, though rough, squally weather occurred on several days. The American S. S. *Peter Kerr*, Panama to San Pedro, reported "moderate gales and rain squalls" from 7° 08′ N., 81° 12′ W., to 15° 27′ N., 96° 56′ W., on October 12 to 17.

In Asiatic waters several typhoons and depressions occurred, and have received treatment elsewhere in this REVIEW. The only report thus far received by the Weather Bureau from a vessel experiencing one of these typhoons is from the American S. S. *Scottsburg*, Honolulu to Manila, and relates to one of the less intense disturbances mentioned in the report by Father Coronas. Said the observer:

> In 13° 57′ N., 128° 40′ E., at 2 p. m., encountered heavy squall with wind shifting from SE. to SSW., increasing from force 3 to force 6, barometer 29.60. At 4 p. m. barometer 29.54, rainy weather with rough head sea. At midnight wind increased to force 7, with 9 during severe squalls, WSW. barometer 29.58, in 13° 30′ N., 26° 45′ E.

A fair idea of the brisk air movements over the northern and central routes may be obtained from the adjoined table of gale and storm reports. The gales were mostly associated with the fluctuating activities of the Aleutian LOW rather than with progressing cyclones.

An especially interesting report is that of the American schooner *Irene*, Honolulu to Grays Harbor. This vessel weathered a series of gales, force 8 to 10, from the 20th to the 30th of the month, while between positions 31° N., 159° W., and 42° N., 137° W. The roughest weather was met with on the 27th and 28th. To quote from the captain's report:

> *27th.*—About 3 a. m. glass started to fall, wind SE. Glass fell rapidly until 7 a. m., when wind hauled SW., barometer 29.36, wind increasing till about force 10, mountainous seas running. After 10 a. m. glass rising slowly, wind about the same in force until midnight. During the time SW. gale was blowing glass was pumping violently, moving as much as two-tenths in the squalls. Kept this up even after the gale moderated and glass had risen to 30.06. During the most of the gale could feel the difference in pressure on eardrums, so much that some of the men could hardly hear when they got below.

VERY FEW TYPHOONS IN THE FAR EAST DURING SEPTEMBER, 1924

By Rev. JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

Up to the present (September 24) not a single depression or typhoon has occurred during this month over or near the Philippines. Even in the whole Far East we have to mention only one well-developed and intense typhoon over the Loochoos and close to Formosa and a few other depressions of no great importance.

The Formosa typhoon, September 3 to 8.—This typhoon appeared on our weather map of the 3d near 136° longitude E. and 22° latitude N. It moved WNW., and at 6 a. m. of the 5th its center was clearly situated in about 127° longitude E. and 25° latitude N. In the early morning of the 6th, when the center was in about 26° latitude N. and 124° longitude E., the typhoon began to move W. by S., passing very close to north Formosa in the afternoon. The lowest barometric minimum

observed in Formosa was that of Keelung 733.7 mm. (28.89 ins.), with hurricane winds from SW. The maximum velocity of the wind was of 48.3 m. p. s. (108 m.p.h.). The following report was received from the director of Taihoku Observatory:

The typhoon was destructive in north Formosa, causing great damage; persons killed, 18; missing, 14; and injured, 312; houses destroyed, 3,300; partially destroyed, 4,060; damaged, more than 6,000: two steamers and more than 50 junks wrecked.

From 6 a. m. of the 7th the typhoon moved west into China along the 25° latitude N.

Other depressions of less importance.—On the 10th a small cyclonic center was observed to the NE. of Formosa, between 124° and 125° longitude E., 25° and 26° latitude N. It moved NNE. across the Eastern Sea on the 11th and then ENE. across central Japan on the 12th.

Another depression was formed over the Eastern Sea on the 16th to 17th near 30° latitude N., between 126° and 127° longitude E. It moved E. by N. on the 18th and 19th to the south of Japan.

A depression traversed the southern part of Japan on the 16th, moving eastward. It is doubtful whether it really formed over the Eastern Sea ESE. of Shanghai on the 14th, or if it developed out of a low-pressure area shown in our weather maps between Hongkong and Shanghai before the 14th. In the latter case, it should be considered as a continental depression.

THE DESTRUCTIVE TYPHOON OF NORTHERN LUZON, OCTOBER 3, AND FIVE OTHER LESS IMPORTANT TYPHOONS OF THE FAR EAST IN OCTOBER, 1924

By Rev. José CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

Both the Pacific and the China Sea were very stormy during the first 8 or 10 days of October. There were three typhoons, which, if not altogether simultaneous during those days, were at least partly so. The most important, however, is that which struck northern Luzon during the night of October 2 to 3 and the morning of the 3d.

Typhoon of northern Luzon, October 3.—This typhoon was shown for the first time in our weather maps on the morning of October 1 about 400 miles to the east of central Luzon near 128° longitude E. and 15° latitude N. It seems to have moved at the beginning NW. by W. and WNW., but gradually inclined more and more to the west, thus threatening the northern part of Luzon. The center traversed Luzon through the central part of Cagayan Province, the northern part of Ilocos Sur, and the southern part of Ilocos Norte. Its actual direction while traversing Luzon was either due west or even perhaps W. by S. Great damage was done not only to the three mentioned Provinces, but also to the Mountain, La Isabela, La Union, and Abra Provinces. It is considered as one of the worst typhoons ever experienced in northern Luzon.

The lowest barometric minima so far reported to our office are: Aparri, 720.63 mm. (28.37 inch) at 4:30 a. m.; Tuguegarao, 720.90 mm. (28.38 inch.) at 4:51 a. m.) on board S. S. *Macaria*, stranded at 17° 46′ latitude N., 120° 24′ longitude E., 724.0 mm. (28.50 inch.) at 10 a. m.; Laoag, 726.69 mm. (28.61 inch.) at 8 a. m.; Vigan, 726.16 mm. (28.59 inch.) at 9:30 a. m.

It has been reported that in Lallo, a town 10 miles south of Aparri, the barometer fell to 707.0 mm. (27.59 inch.). In the China Sea the typhoon continued moving almost due W. with a very little inclination to the north.

The positions of the center at 6 a. m. of the 2d to the 6th are as follows:

October 2, 6 a. m., 126° 45′ longitude E., 16° 25′ latitude N.
October 3, 6 a. m., 121° 15′ longitude E., 18° 00′′ latitude N.
October 4, 6 a. m., 116° 10′ longitude E., 17° 55′ latitude N.
October 5, 6 a. m., 111° 15′ longitude E., 18° 20′ latitude N.
October 6, 6 a. m., 107° 20′ longitude E., 18° 50′ latitude N.

Two Japan typhoons, September 28 to October 9.—On September 28 a depression was formed in the neighborhood of the Loochoos, although it developed into a real typhoon while approaching Japan on the 29th. After moving NE. on the 28th, the typhoon traversed part of Japan and the eastern part of the Japan Sea on the 29th and 30th, moving first NNE., or N. by E., and then NE. At. 6 a. m. of October 1 the center was shown by our weather maps not far from the northernmost coast of Japan.

The other Japan typhoon had its origin in the Western Carolines on September 29. The center was situated at 6 a. m. of that day south of Guam and east of Yap near 145° longitude E. and 9° latitude N. It moved northwestward on September 29 and 30 and October 1; then WNW. on October 2 and 3; and it recurved to N. and NNE. on October 4, when near 130° longitude E. and 19° latitude N. On October 6 it inclined back to WNW. toward the northern part of the Loochoos, but then at about noon of the 7th it recurved again to NE., the center being situated near Kagoshima in the early morning of the 8th. From noon of the 8th it seems to have moved eastward and it was probably only a depression of little importance; but we do not have as yet sufficient observations to verify this.

A Balintang Channel typhoon, October 7 to 11.—This typhoon, like the first one, was apparently formed over the Pacific about 300 or 350 miles to the east of central Luzon. Its center was shown by our weather maps at 6 a. m. of the 7th near 127° longitude E. and 15° latitude N. It moved NW. by W., traversing the Balintang Channel on the morning of the 9th and reaching the China coast between Swatow and Hongkong in the afternoon of the 10th. It was apparently only an ordinary typhoon and not a destructive one, like the first Philippine typhoon of this month.

A Pacific typhoon between Yap and Guam, October 6 to 9.—Although the track of this typhoon is not so certain, as it is based only on the observations made in Guam and Yap, yet it would seem that it formed on October 6 near 142° longitude E. and 9° latitude N. It moved NNW. on the 6th and N. on the 7th and finally it recurved to ENE. on the 8th between 138° and 139° longitude E., 12° and 13° latitude N.

A depression over the Visayas, October 19.—Signs of a depression or typhoon over the Pacific east of the Visayas appeared in the afternoon of the 18th, although the 6 a. m. weather map of October 19 showed clearly that there was only a shallow depression of little importance crossing the southern part of the Visayas in a westerly direction. In the China Sea it moved to WNW., at the same time developing into a real typhoon, which reached the Indochina coast in the early morning of the 23d near 109° longitude E., 14° latitude N.

CYCLONIC DISTURBANCES IN SOUTHERN OCEANS

By ALBERT J. MCCURDY, Jr.

South Atlantic Ocean.—Weather reports thus far received from vessels that traversed the shipping routes of the South Atlantic Ocean in October, 1924, indicate only one disturbance of any consequence.

From the 9th to 12th the American S. S. *Swiftwind*, Capt. A. W. Barlow, Texas City to Buenos Aires, experienced southwesterly gales accompanied by heavy head seas off the coast of Uruguay. Mr. A. C. Allen, second officer, states that the lowest barometer, 29.86 inches, was recorded at 8 p. m. on the 9th in 28° 32′ S., 47° W. The wind at the time of the lowest pressure was SW., force 5. By the 12th the gale had increased to force 10 from the southwest but lasted only until noon.

This same gale was experienced by the American S. S. *Tuscaloosa City*, Capt. R. C. Forbes, New York to Montevideo. Mr. T. W. Marvin, second officer, reports that the lowest barometer noted was 29.85 inches, occurring at 2 a. m. on the 10th in 28° 14′ S., 46° 27′ W. The wind at this time was SW., force 8, later increasing to force 11. With the *Tuscaloosa City* this gale lasted until 2 p. m. of the 12th.

South Pacific Ocean.—Of the cyclonic disturbances occurring in the South Pacific Ocean during October, only one of any significance has been reported. This was a depression off the east coast of New Zealand. The British S. S. *Mahana*, Capt. W. Kershaw, Balboa to Auckland, came within its influence on the 11th, experiencing a west-northwesterly gale accompanied by very heavy seas. Messrs. F. Smith, second officer, and F. Gilroy, fourth officer, report that the lowest pressure was 29.48 inches (uncorrected), occurring at 4 p. m. on the 11th in 34° 47′ S., 168° 42′ W. The wind at this time was WNW., force 8, but later shifted to WSW., and increased to force 9 on the 12th. To quote:

> After blowing force 5 from 2 p. m. on the 12th to 2 p. m. on the 13th the wind increased to gale force, maintaining a steady WNW. direction with barometer only fluctuating very slightly.
>
> At 10 p. m. the wind fell off a little and by 6 a. m. on the following morning was blowing W., force 5, barometer still steady.

DETAILS OF THE WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

By ALFRED J. HENRY

The outstanding feature of the month was the drought that prevailed east of the 100th meridian and to the south of the parallel of about 37° north latitude. In all of this region precipitation was greatly deficient, save only in the Florida Peninsula, where the tropical cyclone of the 17th–21st was the occasion of heavy rainfall. The rainfall, however, did not extend beyond the limits of the State. Associated with the drought, but whether in the relation of cause and effect is not known, was the tendency for anticyclones to persist over Atlantic Coast States, presumably as a result of the frequent renewal of their supply of polar air from higher latitudes. In that position these anticyclones seemed to form an obstacle to the normal eastward movement of cyclonic systems that approached from the west. The text and charts which follow present the usual details.

CYCLONES AND ANTICYCLONES

By W. P. DAY

The persistence of high-pressure areas over the eastern portion of the country was the outstanding feature of the month. Low-pressure areas formed frequently over the Rocky Mountain and Plateau regions, but made very little headway eastward, and in most cases were forced northward and the southern ends of their troughs were closed by high pressure. The failure of these troughs to traverse the country, closely connected with the prevalence of high pressure to the east, are interesting facts in connection with the drought which prevailed over the Middle and North Atlantic States.

The hurricane which developed during the 13th–18th over the northwestern Caribbean Sea passed over the extreme western end of Cuba on the 19th. It caused some of the lowest barometer readings ever recorded in these regions. A land station, Los Arroyos, reported 27.52 inches and two vessels reported under 28 inches.

FREE-AIR SUMMARY

By V. E. JAKL

The outstanding feature of the month was the frequency with which winds having a decided easterly component occurred at various levels throughout the region covered by aerological stations. This marked easterly tendency of the upper winds was apparently associated with the prevalence of stagnant or slowly moving high-pressure areas, which, instead of the usual succession of high and low pressure areas, largely influenced this portion of the country. The unusual condition of general easterly winds prevailing for a period of days over a considerable portion of the country was observed twice during the month. From the 10th to 12th and from the 20th to 25th, particularly during the latter period, easterly winds to high altitudes were observed with great regularity at nearly all aerological stations. In addition, easterly winds were observed quite frequently on scattered dates and over scattered areas. In the resultants for the month, however, the easterly component is apparent only in the South. Elsewhere east of the Rocky Mountains the resultant winds—especially in the lower 3,000 meters—show a circulation completing the anticyclonic circuit; i. e., southerly over the Mississippi Valley, westerly over the Lake region, and northerly over the Atlantic States. This distribution of resultant winds naturally resulted from the average high pressure for the month over the eastern half of the country.

The effect of the resultant winds on the mean upper-air temperatures is apparent from the figures in Table 1. Broken Arrow, Drexel, and Ellendale, which had winds decidedly more southerly than normal at all altitudes, showed temperatures well above the normal throughout the vertical column. At Royal Center, with normal winds from a general westerly direction, the temperature was also above normal at all levels, due to drainage from the abnormally warm region to the west. At Groesbeck, the most southerly kite station, where the winds were of normal direction and strength from about south, the temperature was very close to normal, while at Due West, another southern station, where winds had a decided northerly component, the temperature was perceptibly below normal for all altitudes observed.

Records of humidity showed no important features, except at Broken Arrow, Drexel, and Ellendale, where with temperature above normal the relative humidity was the same as normal. Consequently, the vapor pressure at these stations was decidedly above normal. Notwithstanding this higher average vapor content of

the air, precipitation during the month, although abundant at Ellendale, was very light at Broken Arrow and Drexel. The explanation is to be found in the fact that Ellendale was more often under the disturbing influence of low-pressure areas than Broken Arrow or Drexel.

A number of instances of high velocities aloft were recorded during the month, both in connection with occasional low pressure areas, and, at very high altitudes, in connection with the weak to moderate HIGHS that were the prevailing pressure condition. Only such instances are mentioned as were recorded in two-theodolite pilot-balloon observations, or otherwise substantiated, as by kite observation or by simultaneous observation at adjoining stations. In connection with high-pressure areas, in a series of five two-theodolite observations made at Broken Arrow on the 14th, light velocities, averaging about 3 m. p. s., prevailed up to nearly 7,000 meters, above which the velocity increased rapidly in the next few thousand meters. Velocities exceeding 40 m. p. s., with a maximum of 50 m. p. s., were observed in every observation at altitudes above 10,000 meters. Throughout this series the wind was prevailingly southeast up to 3,000 to 4,000 meters, above which it changed rather abruptly to a solid nothwesterly current extending to the upper limits of the observations. On this date Broken Arrow was situated in the far southwestern portion of an extensive area of moderately high pressure. A two-theodolite observation made at Due West on the 2d, also in the southwestern portion of a high-pressure area, showed a parallel condition, i. e., an east wind to 3,000 meters, changing abruptly to a solid northwesterly wind that extended to 11,500 meters, with light velocity to 6,000 meters, but increasing steadily thereafter to 31 m. p. s. at the highest point of the observation.

In connection with low-pressure areas, single-theodolite observations made nearly simultaneously at Drexel and Ellendale on the 31st, showed at the former station a steady rise in velocity from 5 m. p. s. on the ground to 52 m. p. s. at 6,600 meters, and at the latter station, a steady rise from 7 m. p. s. on the ground to 62 m. p. s. at 7,300 meters. These observations were made a considerable distance to the southwest of the center of a well-defined LOW, the winds observed at both stations having been from westerly near the ground to northwest in the upper altitudes.

Further examples of the rapid increase in velocity with altitude characteristic of the regions apparently just outside of the influence of deep low-pressure areas to the north are given in the kite flights at Drexel on the 5th and 12th. In the former observation, a wind of 6 m. p. s. on the ground increased to 39 m. p. s. at 4,300 meters, and in the latter a velocity of 4 m. p. s. on the ground became 34 m. p. s. at 3,100 meters.

A two-theodolite observation made at Ellendale on the 14th showed a very abrupt rise in velocity from 2 m. p. s. on the ground to 18 m. p. s. at 500 meters above the ground in a south wind. Although this observation was made directly to the east of a weak LOW that apparently was developing strength, the abrupt rise in velocity appeared to belong to a type of wind increase with altitude common to the Plains States in connection with nocturnal temperature inversions, particularly in south winds, and as yet not satisfactorily explained.

The instances cited show some of the peculiarities of change of velocity with altitude, a knowledge of which beforehand would be of great value to aircraft. Some unusual arrangement of wind direction with altitude is also occasionally observed. An example of reversal of the usual change in direction with altitude is shown in the two-theodolite observation made at Ellendale on the 25th. Ordinarily a wind of any direction near the ground becomes westerly at some altitude aloft. Ordinarily, also, easterly winds at high altitudes are light. On this date a wind of moderate strength from the southwest, changed abruptly to a strong wind from nearly due east at about 4,000 meters, the easterly wind prevailing from that altitude up to nearly 13,000 meters. On the following day approximately the same wind structure was observed at Lansing and Madison in single-theodolite observations extending to about 6,000 and 8,000 meters, respectively.

An illustration of marked convectional activity in a cumulo-nimbus cloud is given in the kite observation made at Broken Arrow on the 9th. During this observation the kite carrying the meteorograph broke from the line when about 2,700 meters high, and was carried upward about 400 meters by an ascending current. After reaching the top of the ascending current the kite fell to the ground. From the computed rate of ascent and descent it is evident that the current in which the kite was carried upward had a vertical velocity of at least 5.4 meters per second. This velocity is in agreement with the ascending velocity occasionally determined from observations made in pronounced convectional currents by the two-theodoloite pilot-balloon method. From the following table, showing the meteorological conditions recorded during the flight, it will be noted that the lapse rate of temperature at the altitude in which the kite was carried upward exceeded the dry adiabatic.

Meteorological conditions over Broken Arrow, Okla., on October 9, 1924:

Altitude, M. S. L. (meters)	Temperature (° C.)	$\frac{\Delta t}{100\ m}$	Relative humidity (per cent)
233 (surface)	18.9		79
673	20.0	−0.25	77
984	18.4	0.51	76
1,119	20.0	−1.19	71
1,316	17.1	1.47	85
2,312	11.3	0.58	57
2,330	11.0	1.67	85
2,504	11.7	−0.40	62
3,361	3.0	1.02	85
4,137	−2.4	0.70	78

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during October*

TEMPERATURE (° C.)

Altitude m. s. l. (m.)	Broken Arrow, Okla. (233 m.)		Drexel, Nebr. (396 m.)		Due West, S. C. (217 m.)		Ellendale, N. Dak. (444 m.)		Groesbeck, Tex. (141 m.)		Royal Center, Ind. (225 m.)	
	Mean	Departure from 7-yr. mean	Mean	Departure from 9-yr. mean	Mean	Departure from 4-yr. mean	Mean	Departure from 7-yr. mean	Mean	Departure from 7-yr. mean	Mean	Departure from 7-yr. mean
Surface	17.7	+0.6	14.4	+2.6	14.6	−1.3	9.4	+1.4	17.4	−1.4	15.1	+1.0
250	17.7	+0.7			14.2	−1.4			18.4	−0.3	15.0	+1.0
500	17.8	+1.9	14.5	+3.0	12.2	−1.6	9.8	+1.6	18.5	+0.7	14.3	+1.6
750	16.9	+2.1	14.6	+3.9	11.0	−1.6	11.7	+3.5	17.2	+0.5	13.1	+1.7
1,000	15.9	+2.2	13.8	+3.9	10.0	−1.6	11.7	+4.1	15.7	+0.3	11.8	+1.7
1,250	14.6	+1.9	12.7	+3.5	9.4	−1.2	11.0	+4.2	14.4	+0.1	10.5	+1.6
1,500	13.3	+1.6	11.6	+3.3	8.7	−1.0	9.8	+3.9	13.4	+0.2	9.6	+1.9
2,000	10.7	+1.2	9.7	+3.7	7.3	−0.6	7.3	+3.6	11.9	+0.9	7.0	+1.6
2,500	8.3	+1.3	7.1	+3.8	5.9	−0.5	4.3	+3.1	9.6	+0.9	4.2	+1.2
3,000	5.5	+1.3	4.4	+3.8	3.7	−0.5	1.2	+2.7	7.3	+0.7	1.2	+0.6
3,500	2.4	+1.1	2.0	+4.1	0.7	−0.8	−1.5	+2.8	4.6	+0.2	−1.5	+0.4
4,000	−0.4	+1.1	−0.1	+4.5	−2.5	−1.2	−5.3	+1.7	2.0	0.0	------	------
4,500	−1.2	+2.8	−2.7	+4.2	−5.4	−1.5	------	------	−1.5	−0.5	------	------
5,000	------	------	−5.3	+5.1	−8.0	−1.5	------	------	−4.8	−0.8	------	------

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during October*—Continued

RELATIVE HUMIDITY (%)

Altitude m. s. l. (m.)	Broken Arrow, Okla. (233 m.)		Drexel, Nebr. (396 m.)		Due West, S. C. (217 m.)		Ellendale, N. Dak. (444 m.)		Groesbeck, Tex. (141 m.)		Royal Center, Ind. (225 m.)	
	Mean	Departure from 7-yr. mean	Mean	Departure from 9-yr. mean	Mean	Departure from 4-yr. mean	Mean	Departure from 7-yr. mean	Mean	Departure from 7-yr. mean	Mean	Departure from 7-yr. mean
Surface	65	−1	61	0	58	−4	74	+7	71	−2	67	+1
250	64	−2			58	−4			63	−7	67	+1
500	55	−7	58	−1	57	−5	71	+6	54	−12	60	−3
750	52	−9	52	−5	54	−8	60	0	53	−13	60	−1
1,000	51	−9	50	−5	52	−9	56	−2	53	−12	59	−1
1,250	52	−6	49	−4	50	−9	54	−2	53	−10	57	−1
1,500	52	−4	50	−2	48	−9	52	−1	49	−12	52	−3
2,000	49	−1	49	−3	42	−10	50	0	38	−17	48	−2
2,500	44	−1	47	−4	33	−11	50	+2	35	−15	48	+2
3,000	41	0	44	−5	31	−11	52	+5	32	−11	52	+9
3,500	43	+3	38	−9	29	−11	54	+7	31	−9	42	+1
4,000	39	+3	36	−9	28	−10	56	+11	31	−6		
4,500	32	+2	35	−8	28	−9			36	−3		
5,000			34	−8	28	−9			36	−3		

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during October*—Continued

VAPOR PRESSURE (*mb.*)

Altitude m. s. l. (m.)	Broken Arrow, Okla. (233 m.)		Drexel, Nebr. (396 m.)		Due West, S. C. (217 m.)		Ellendale, N. Dak. (444 m.)		Groesbeck, Tex. (141 m.)		Royal Center, Ind. (225 m.)	
	Mean	Departure from 7-yr. mean	Mean	Departure from 9-yr. mean	Mean	Departure from 4-yr. mean	Mean	Departure from 7-yr. mean	Mean	Departure from 7-yr. mean	Mean	Departure from 7-yr. mean
Surface	13.07	+0.12	10.19	+1.48	9.74	−1.61	8.70	+1.52	14.77	−1.49	11.52	+0.75
250	13.00	+0.15			9.53	−1.66			14.26	−1.36	11.39	+0.74
500	11.76	+0.18	9.84	+1.43	8.14	−1.92	8.60	+1.51	12.52	−1.58	9.92	+0.54
750	10.72	+0.15	8.94	+1.26	7.20	−2.07	8.14	+1.49	11.25	−1.83	9.10	+0.70
1,000	9.87	+1.08	8.21	+0.18	6.53	−2.02	7.51	+1.39	10.28	−1.66	8.39	+0.75
1,250	9.21	+0.41	7.59	+1.06	5.99	−1.71	6.83	+1.28	9.52	−1.26	7.38	+0.56
1,500	8.46	+0.56	7.13	+1.10	5.47	−1.38	6.08	+1.10	8.18	−1.44	6.36	+0.36
2,000	6.61	+0.63	6.12	+0.98	4.36	−1.08	4.96	+0.94	5.31	−2.01	4.92	+0.29
2,500	4.96	+0.41	5.00	+0.82	3.48	−0.63	4.03	+0.75	4.02	−1.71	4.24	+0.58
3,000	3.77	+0.30	3.90	+0.60	3.06	−0.39	3.40	+0.74	3.05	−1.25	3.81	+0.87
3,500	3.00	+0.27	2.99	+0.38	2.85	0.00	2.82	+0.65	2.32	−1.13	2.54	+0.20
4,000	2.12	+0.04	2.57	+0.45	2.63	+0.18	2.13	+0.45	1.94	−0.84		
4,500	1.47	−0.11	2.28	+0.51	2.49	+0.24			1.62	−0.84		
5,000			1.99	+0.55	2.39	+0.29			1.47	−0.77		

TABLE 2.—*Free-air resultant winds (m. p. s.) during October, 1924*

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters)				Drexel, Nebr. (396 meters)				Due West, S. C. (217 meters)			
	Mean		4-year mean		Mean		9-year mean		Mean		4-year mean	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 7° E.	5.1	S. 2° E.	2.5	S. 14° E.	2.9	S. 21° W.	1.6	N. 55° E.	5.5	N. 50° E.	2.8
250	S. 8° E.	5.2	S. 2° E.	2.7					N. 52° E.	5.6	N. 50° E.	3.2
500	S. 4° E.	7.2	S. 5° W.	3.8	S. 6° E.	3.1	S. 26° W.	2.1	N. 61° E.	8.5	N. 54° E.	4.4
750	S. 2° W.	8.0	S. 10° W.	4.5	S. 7° W.	7.8	S. 36° W.	3.7	N. 64° E.	10.5	N. 61° E.	4.6
1,000	S. 7° W.	7.3	S. 18° W.	4.4	S. 12° W.	9.6	S. 46° W.	4.2	N. 57° E.	8.8	N. 61° E.	3.6
1,250	S. 19° W.	7.5	S. 31° W.	4.4	S. 22° W.	9.6	S. 54° W.	4.8	N. 59° E.	8.8	N. 68° E.	3.0
1,500	S. 21° W.	7.0	S. 39° W.	4.4	S. 26° W.	9.1	S. 62° W.	5.4	N. 59° E.	8.2	N. 68° E.	1.9
2,000	S. 24° W.	6.7	S. 46° W.	4.7	S. 40° W.	9.5	S. 72° W.	7.0	N. 61° E.	5.1	N. 20° E.	0.4
2,500	S. 33° W.	6.8	S. 59° W.	5.1	S. 48° W.	10.3	S. 76° W.	8.2	N. 43° E.	6.2	N 69° W	2.0
3,000	S. 37° W.	7.6	S. 63° W.	6.0	S. 61° W.	11.1	S. 81° W.	9.5	N. 42° E.	4.9	N. 88° W.	3.2
3,500	S. 54° W.	7.4	S. 70° W.	7.2	S. 50° W.	9.9	S. 87° W.	10.2	N. 26° E.	4.7	N. 81° W.	5.2
4,000	S. 46° W.	7.2	S. 62° W.	8.4	S. 69° W.	13.1	S. 86° W.	11.3	N. 20° E.	3.9	S. 87° W.	6.5
4,500	S. 33° W.	3.4	S. 76° W.	9.0	S. 83° W.	15.8	N. 87° W.	12.2	N. 1° W.	1.9	N. 71° W.	5.7
5,000	S. 45° E.	9.1	S. 71° W.	9.8	S. 72° W.	16.5	N. 85° W.	11.8	N. 47° W.	3.3	N. 34° W.	6.9

Altitude, m. s. l. (meters)	Ellendale, N. Dak. (444 meters)				Groesbeck, Tex. (141 meters)				Royal Center, Ind. (225 meters)			
	Mean		7-year mean		Mean		7-year mean		Mean		7-year mean	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 29° W.	1.7	N. 79° W.	1.6	S. 66° E.	1.8	S. 71° E.	0.9	S. 1° E.	2.2	S. 42° W.	2.2
250					S. 47° E.	3.2	S. 50° E.	1.6	S. 2° E.	2.4	S. 41° W.	2.4
500	S. 16° W.	2.5	W.	1.7	S. 25° E.	4.7	S. 27° E.	2.9	S. 27° W.	5.0	S. 51° W.	4.5
750	S. 18° W.	4.2	S. 85° W.	2.6	S. 18° E.	4.7	S. 17° E.	3.1	S. 52° W.	5.3	S. 61° W.	5.7
1,000	S. 27° W.	4.9	S. 86° W.	3.1	S. 14° E.	4.4	S. 8° E.	2.9	S. 70° W.	5.4	S. 68° W.	6.3
1,250	S. 32° W.	5.4	S. 87° W.	3.8	S. 17° E.	3.9	S. 2° W.	2.9	S. 74° W.	4.4	S. 72° W.	6.9
1,500	S. 39° W.	5.6	S. 87° W.	4.5	S. 27° E.	3.4	S. 15° W.	2.7	S. 79° W.	4.6	S. 76° W.	7.7
2,000	S. 51° W.	6.6	N. 89° W.	6.1	S. 22° E.	1.9	S. 41° W.	2.4	S. 84° W.	6.4	S. 80° W.	9.0
2,500	S 47° W.	8.2	N 85° W	7.5	S. 2° W.	2.1	S. 52° W.	2.7	S. 89° W.	6.9	S. 85° W.	9.8
3,000	S. 49° W.	8.8	N. 86° W.	8.8	S. 17° W.	3.4	S. 57° W.	3.4	N. 83° W.	7.2	S. 87° W.	10.7
3,500	S. 49° W.	9.6	N. 87° W.	10.6	S. 31° W.	3.7	S. 46° W.	3.5	S. 89° W.	11.5	S. 84° W.	12.9
4,000	S. 51° W.	12.1	N. 89° W.	11.4	S. 52° W.	3.3	S. 49° W.	2.7	W.	18.0	S. 83° W.	12.2
4,500	S. 54° W.	14.8	S. 79° W.	13.3	S. 74° W.	8.9	S. 70° W.	2.2				
5,000					S. 67° W.	14.1	N. 57° W.	4.0				

THE WEATHER ELEMENTS

By P. C. DAY, In Charge of Division

PRESSURE AND WINDS

The chief factor in the history of the weather for October, 1924, was the persistence of anticyclonic conditions that centered over the Ohio Valley and northeastern districts almost continuously during the month. This in large measure obstructed the eastward movements of cyclones that formed over the Southwest or entered the United States from the North Pacific, forcing them, after reaching the Great Plains, to pursue northerly courses, mostly to westward of Lake Superior, instead of their usual easterly or southeasterly courses into the Mississippi Valley and thence toward New England. As a result, no cyclone of importance crossed the central valleys and eastern districts, and the month as a whole over these districts was remarkably free from storms of any character. Moderate temperatures were the rule, sunshine was constant for long periods, little or no rain occurred, opportunity was afforded for late crops to mature, and all outdoor operations went forward without material interruption.

Among the cyclones that advanced from the far West and threatened the interior districts the most important were as follows:

On the 3d low pressure advanced from the British Northwest, and by the 4th it was central over western Kansas. High pressure to the eastward barred its further movement in that direction and it was forced northward, and by the morning of the 5th had advanced to the western end of Lake Superior. It was attended by rather general, but mostly light rains.

About the 8th a low-pressure area had advanced from the far Southwest to eastern Colorado, where it had attained considerable severity. High pressure moving southward over the Great Lakes again obstructed the eastward movement, and by the following morning the center had advanced to eastern North Dakota and precipitation had occurred over much of the central and northern Plains.

Promptly following the above, another disturbance pursued a similar course from the far Southwest and was central over western Colorado on the morning of the 11th, whence it also took a northerly and even northwesterly course over the Dakotas to the Canadian Provinces. This was attended by some heavy rains in northern Arizona on the 7th, by heavy snow in the mountains of Colorado on the 8th, and by general rains over the northern Rocky Mountains and the adjacent plains to the eastward.

The middle decade of the month, save as noted above, was remarkably free from stormy conditions in all parts

of the country, except along the immediate north Pacific coast where rains were somewhat frequent during the early part. By the end of the decade, however, a storm of tropical origin had moved from western Cuba to Florida and during the night of the 20th–21st crossed the southern portion of the peninsula, attended by high winds and heavy rainfall, a full report of which will be found elsewhere in this issue.

The last decade of the month was without important cyclonic activity from the Rocky Mountains eastward, save about the 26th and 27th, when a slight barometric depression moved over central Florida and northward along the Atlantic coast to the Chesapeake Bay region, attended by local light to moderate rains over most southeastern districts, and at the end of the month, when a cyclone moved from the middle Plains to the vicinity of western Lake Superior attended by mostly light rains over the middle and upper Mississippi Valley and the western portion of the upper Lake region.

Over the Pacific Coast States the last decade had frequent rains from northern California to Washington, and the last few days of the month brought needed rain to southern California and over much of the Plateau region.

The average pressure for the month was above normal over all eastern and practically all southern districts of the United States and over the eastern Canadian Provinces as far northward as observations extended, the center of highest pressure covering the Ohio Valley, lower Lake region, and northeastern districts.

From the northern Plains and central Rocky Mountain region westward to the Pacific average pressures were mainly below normal, and similar conditions existed in the western Canadian Provinces.

Due to the passage of a tropical storm over southern Florida, with attendant low pressures, the monthly averages over that area were slightly below normal.

The absence of cyclones over the central and eastern districts, save for the tropical storm that passed over southern Florida, favored an unusually stable condition of the atmosphere, and the wind movement was nearly everywhere light, in some instances the least of record for October. Local high winds were largely absent throughout the region, save over southern Florida in connection with the severe storm referred to above.

Due to persistent high pressure over the Ohio Valley and to the northeastward, the prevailing winds were mainly from the northeast over the Atlantic coast districts and East Gulf States and lower Ohio Valley, and from southerly points in most of the Great Plains, upper Mississippi Valley, and Great Lakes. Over the Dakotas and adjacent areas the prevailing winds, usually from cold northerly points at this season of the year, were mainly from the Southeast, carrying the warmer air of those regions far northward into the western Canadian Provinces.

TEMPERATURE

The month as a whole was notable for the small temperature variations, due mainly to the lack of important pressure changes. This was particularly the case over the districts from the Mississippi Valley eastward, where practically no daily change as great as 20° was observed until the last day of the month.

At the beginning of the month some unusually low temperatures prevailed over the eastern districts as an extensive cool area, overspreading the central and western districts at the close of September, moved eastward to the Atlantic coast. Warmer weather immediately followed and the average temperature for the first week was not far from the normal, being generally below normal in the Southeast and Northwest, and slightly above in other portions.

The period from the 7th to 14th was mainly warm over the interior portions of the country, the average ranging up to nearly 10° above normal in the central valleys. Over the districts west of the Rocky Mountains the week was mainly cool, and it was cool over the Atlantic Coast States also.

The third week was warmer than normal over all parts of the country save in the extreme Northeast and over the middle and southern Plateau and Pacific coast sections. Over the central valleys this week, also, was abnormally warm, the averages ranging from 6° to 15° above the normal.

The last decade of the month was mainly warmer than normal over all northern districts until near the end, when decided changes to cooler occurred over the middle and southern Plateau and Rocky Mountain regions, advancing at the end of the month into the Great Plains and middle Mississippi Valley.

The periods of highest temperature were about the first of the month over most sections from the Great Plains westward, about the 3d to 5th over the Gulf States, and generally during the first decade over many of the remaining districts.

The lowest temperatures were confined mainly to the last decade, though west of the Rocky Mountains they occurred mostly from the 10th to 12th.

The average temperatures were above normal in all portions save over the Atlantic Coast States and the middle and southern Plateau and Pacific Coast States, where the month was slightly cooler than normal. Over the great central valleys and upper Lake region the month as a whole was decidedly warm, the averages ranging up to nearly 10° above normal, and this condition existed in the western Canadian Provinces also, as far north as observations are available at this time. At points in the Dakotas and surrounding States the month was the warmest of record for October, while farther south it was among the warmest.

PRECIPITATION

October was an unusually dry month over practically all the eastern half of the country, except in the Florida Peninsula. Much of the territory from the eastern Great Plains to the Atlantic coast had less than 1 inch of precipitation during the entire month, while a wide area from central Texas northeastward to the Ohio Valley, Great Lakes region, and Northeastern States had less than one-half inch. Many localities in this area had none or not more than a trace. Over much of this area it was the driest October in the periods of record, ranging up to 100 years or more in portions of New England and to 50 years or more locally in the Great Lakes region and southward over the Ohio Valley to the West Gulf States.

In portions of the lower Mississippi Valley and eastern Texas there was practically no rain and as several months preceding have been the driest, or among the driest, of record, the drought conditions at the end of the month were locally the severest known. Conditions only slightly less dry prevailed in many portions of the Ohio Valley, Lake region, and North Atlantic States, though here the precipitation of preceding months had been more generous, particularly over the Atlantic Coast States,

where heavy rains at the end of September thoroughly saturated the soil, so that, despite the lack of rain for unusual periods of time, the water supply was sufficient for current needs except in local areas, where severe shortage existed. The month was unusually favorable for forest fires in the East and these occurred to a considerable extent over the larger forested areas.

Over the districts from the Dakotas, western Nebraska, and Colorado to the Pacific coast, precipitation was mainly well distributed through the month and in sufficient quantity to meet present needs. In fact, at points near the coast from northern California to Washington the month was decidedly wet, some localities having the greatest precipitation of record in October, effectually ending one of the severest droughts ever known in that region. In California particularly, where drought had persisted for so many months, the water shortage was greatly relieved and the forest-fire hazard, which had become acute, was terminated for the season.

Over the Florida Peninsula precipitation was unusually heavy, particularly near and along the Atlantic coast, where the monthly amounts ranged up to nearly 40 inches. These heavy falls were mainly associated with the passage of the tropical storm that moved over the southern portion on the 20th and 21st, although many of the greatest daily falls occurred in connection with a period of unusually heavy precipitation from the 4th to 11th. Marked contrasts are shown in the total amounts of precipitation for different parts of the State, the extreme northwestern portion having in some cases less than a quarter of an inch, while nearly 40 inches were recorded on the middle eastern coast.

SNOWFALL

But little snow was reported during the month over the districts east of the Rocky Mountains. In the far West, over all central and northern portions, there was more or less snow, depending on elevation, the amounts ranging up to 40 inches or more in the Sierra of central California and to nearly 60 inches in the Cascades of Oregon. In the main system of the Rocky Mountains the amounts ranged up to 30 inches in the high ranges of Colorado and to somewhat less in the more northern portions.

RELATIVE HUMIDITY

The percentage of moisture in the atmosphere was much less than normal in the central and western Gulf States, and generally over the middle and southern Plains and the middle Mississippi and lower Ohio Valleys, also locally in the Middle Atlantic States. Elsewhere the departures from normal were not important, being mostly negative except over the Florida Peninsula and portions of the Pacific States and the Plateau region.

SUNSHINE AND CLOUDINESS

From the Great Plains eastward there was mainly abundant sunshine, except over the Florida Peninsula, where cloudy weather and rain prevailed to an unusual extent. In portions of the lower Mississippi Valley and West Gulf States sunshine ranged from 75 to 90 per cent of the possible. From the Rocky Mountains westward, sunshine was generally somewhat less, considerably so in the far Northwest, but this is to be expected.

SEVERE LOCAL HAIL AND WIND STORMS, OCTOBER, 1924

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annua Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Value of property destroyed	Character of storm	Remarks	Authority
Portales, N. Mex. (6 miles east of)	2	2 p. m.			Whirlwind	Framework of Rogers school building demolished; one person badly injured.	The Mexican (Santa Fe, N. Mex.). Official, U. S. Weather Bureau.
Southern Florida	20-21				Tropical winds	Shipping delayed; chief damage to truck and citrus fruits. Citrus crop damaged to the extent of 1,000,000 boxes. Considerable property loss by flooding.	Do.
Black Hawk County, Iowa	30		100	$75,000	Tornado and rain	Many plate-glass windows and trees broken; wire systems demoralized; buildings unroofed; merchandise damaged by rain.	Do.
Fayette County, Iowa	30				Wind	Many farm buildings wrecked, livestock killed, and considerable hay blown away.	Do.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

The first storm warnings of the month were displayed on the Alabama, Mississippi, Louisiana, and extreme northwest Florida coast in connection with a disturbance of slight intensity that developed over the east-central portion of the Gulf of Mexico during the 11th–12th. It apparently moved almost directly westward for 24 to 36 hours and then was deflected toward the southwest by a strong area of high pressure that covered practically the entire United States. No strong winds were reported from the land stations, but one vessel in the north-central Gulf reported 56 miles an hour from the northeast on the 12th and another a short distance from Tampico, Mexico, reported the same velocity from the northwest on the 14th. Shortly thereafter the disturbance apparently was dissipated before reaching the coast of Mexico.

At 9:20 p. m. of the 14th, when the last advisory warning regarding the disturbance described above was issued, the following additional information was included:

Reports from northwestern Caribbean Sea indicate disturbance is developing northwest of Swan Island. Caution advised vessels departing for Yucatan Channel.

From this time until the evening of the 22d, when the storm was centered in about latitude 28° N. and longitude 71° W., twice daily advisories were issued regarding its location, intensity, and direction of movement. Until the evening of the 17th, when the storm had reached the proportions of a hurricane and was central about 100 miles west-southwest of Swan Island, it was difficult to locate the storm center definitely. There was apparently some retrograde movement during the 16th–17th, as the wind at Swan Island, which was moderate to fresh southwest and west on the 15th, gradually backed to southeast with little change in velocity and with very slowly falling barometer. During the night of the

17th–18th there was a marked increase in the force of the wind to 44 miles an hour at the a. m. observation of the 18th. The same morning, at 5 a. m., special observation from the U. S. S. *Denver* in latitude 17° 20′ N. and longitude 85° 50′ W. showed a barometer reading of 28.92 inches and a wind force of 12 from the southwest. Another valuable report from this vessel at 8 a. m. showed a 2-hour rise in barometer of 0.20 inch, which plainly indicated that the storm had at last begun to move northward, this information being included in the morning advisory warning of that date. The following warning was issued at 9 p. m. of the 18th:

Hurricane central about 20 north 86 west, apparently moving almost directly northward, attended by dangerous shifting gales. Vessels bound for southeastern Gulf of Mexico and Yucatan Channel should exercise every precaution. Hurricane will probably pass through Yucatan Channel or over extreme western Cuba late to-night or Sunday morning. Storm warnings extended northward to Cedar Keys and Titusville.

The hurricane passed over extreme western Cuba in the vicinity of Corrientes Bay before noon of the 19th according to information received later. At 9:30 a. m. of that date the following advisory warning was issued:

Hurricane warnings ordered 10:30 a. m. Jupiter to Punta Gorda, Fla., and northeast storm warnings extended northward to Jacksonville and Apalachichola. Hurricane center approaching extreme western end of Cuba, apparently moving north-northeastward, attended by dangerous shifting gales. Dangerous for vessels next 36 hours Florida Straits, southeastern Gulf of Mexico, and off southeast Florida coast.

At 5 p. m. of the 19th hurricane warnings were ordered displayed north of Punta Gorda to Cedar Keys. After reaching latitude 25 N. the hurricane turned rather sharply toward the east and passed inland near Cape Romano, Florida, about 50 miles south of Fort Myers, at about 8 p. m. of the 20th. It passed almost directly eastward over the Florida Peninsula with diminishing intensity, the center reaching the Atlantic Ocean some distance north of Miami on the morning of the 21st. The motor ship *Mexico* in latitude 26° 17′ N. and longitude 79° 26′ W., reported that the hurricane center passed at 10:20 a. m. The hurricane continued to move eastward until it passed beyond Great Abaco Island, Bahamas, after which it moved in an east-northeasterly direction. No reports were received from the region east of the Bahamas after the morning of the 22d. However, it is probable that the storm, with greatly diminished intensity, passed south of Bermuda on the morning of the 23d.

This hurricane was one of the worst ever known in extreme western Cuba; therefore a short description of its effects there and over the extreme southeastern portion of the Gulf of Mexico is given on page 513.

Frost warnings were issued on numerous dates during the month, the most important being those in connection with the cool wave that progressed steadily southward from Canada to the Gulf coast during the 20th–24th. On the latter date light frost formed as far south as Mobile, Ala., and heavy frost to Meridian, Miss., and Macon, Ga.—*C. L. Mitchell.*

CHICAGO FORECAST DISTRICT

Frost warnings.—At the beginning of the month the growing season had come to an end in most of Montana and Wyoming, but elsewhere in the district frost warnings were still required. Accordingly, these were issued from time to time as the conditions seemed to warrant, but as the month advanced the area where the warnings were needed became more and more restricted. In the eastern and southern protions of the district, the week beginning on the 21st was cool and frosty, and killing frost occurred extensively. Frost warnings during the remainder of the month were needed only for a few limited sections, mainly in the extreme southern portion of the forecast district.

Cranberry marsh warnings.—The frost-warning service for the benefit of the cranberry interests in Wisconsin was terminated on the 7th, at which date most of the crop had been gathered. Several letters of appreciation for the services rendered during the 1924 season have been received.

Stock warnings.—The only livestock warnings issued were those of the 10th and 11th for Wyoming or portions thereof. In both instances the advices appear to have been justified.

Fire-weather warnings.—Fire-weather warnings were begun on the 25th for the benefit of the Forest Service at East Tawas, Mich., and were being continued at the close of the month.

Storm warnings.—No general severe storm affected the Great Lakes during the month, but one of considerable intensity prevailed over Lake Superior on the closing day. In two instances disturbances that developed marked intensity over the middle Rocky Mountain region were diverted from the normal course leading toward the Great Lakes by the presence of high-pressure area over the Northeast, and thus were forced to take a north-northeast or even a directly north track that carried the center into Canada far to the west of Lake Superior.

The most important disturbed periods were those covering the 5th, 8th–9th, and 30th–31st. On the morning of the 5th storm warnings were issued for the Upper Lakes, in connection with a disturbance then over northern Minnesota. The warnings were lowered 12 hours later, when it was evident that the storm was decreasing in energy. At most points where the displays were made strong winds occurred, and at Chicago the force of a moderate gale was reached.

On the 8th and 9th warnings were issued for Lake Superior and northern Lake Huron for a disturbance that moved northeastward from Colorado on the former date, at the same time losing energy. The center passed to the northward west of Lake Superior, and moderate gales occurred over most of Lake Superior on the afternoon of the 9th.

The last storm warning of the month, and the most important one, was that issued on the 30th. On the morning of that date a disturbance of considerable depth was over eastern South Dakota, while to the eastward, with its crest over the St. Lawrence Valley, lay a marked area of high pressure. The storm took a northeastward course and 24 hours later was centered north of Lake Superior. General storm warnings were issued in this connection, and in most cases verifying winds occurred. On Lake Superior the storm was rather severe. After subsiding on the 31st it underwent a redevelopment on the night of October 31–November 1, so that warnings had to be displayed again.—*C. A. Donnel.*

NEW ORLEANS FORECAST DISTRICT

Troughs of low pressure, forming in rapid succession over the Western States during the first decade, showed well-defined development on the eastern slope of the Rocky Mountains, but thereafter weakened and were displaced rapidly northward without having marked influence on the weather in this district. During the last few days of the month another trough, with strong

barometric gradient, behaved in similar manner. High pressure dominated conditions at most other times. Due to these conditions, the weather was abnormally dry in the eastern and central portions of the district, with much greater fire hazard than usual and much accumulation of smoke from numerous grass and small forest fires.

A moderate Gulf disturbance caused maximum wind velocities of 30 and 24 miles an hour from the east at Burrwood and New Orleans, respectively, early in the afternoon of the 12th. As the disturbance moved westward some distance off the shore the effects at other land stations in the district was less marked. Northeast storm warnings were ordered by the Washington office westward to Burrwood in the morning of the 12th, for the remainder of the Louisiana coast at night on the 12th, and for the middle and west coasts of Texas on the morning of the 13th. Small craft warnings were displayed at West End, on Lake Pontchartrain on the 12th, from 10 a. m. until night, and were justified. Small craft warnings were displayed also by the official in charge at Corpus Christi, Tex., on the 30th.

After a slow-moving tropical storm had passed eastward over southern Florida on the 21st, the conditions in the Gulf States remained under the influence of a large, sluggish area of high pressure for about a week, with daily frosts in most interior sections. These frosts were generally forecast. Frost warnings issued earlier in the month on the 5th and 8th for the extreme northwestern portion of the district were not justified, owing to cloudiness or insufficient cooling.

Fire-weather warnings were issued for forest areas in Oklahoma on the 8th, 11th, and 29th and in Arkansas on the 8th, 29th, and 30th, and conditions occurred as forecast.—*R. A. Dyke.*

DENVER FORECAST DISTRICT

Frequent precipitation in Colorado during the first two decades of the month, and occasional rains in the remainder of the district, resulted from a succession of storms that advanced eastward from the southern Plateau region. Heavy rains fell in northern Arizona on the 7th and heavy snows occurred in the mountains of Colorado on the 8th. After the 20th the important storms passed to the northward of the district and generally fair weather prevailed until the 29th, when snow or rain in Utah and Colorado attended a storm of decided intensity that moved southeastward from the north Pacific coast.

Special warnings were issued as follows: 2d, frost in northern New Mexico, heavy frost in Colorado and Utah, with freezing temperatures at the higher elevations of Colorado, Arizona, and Utah; 3d, frost in northern New Mexico; 4th, frost in Colorado, northern New Mexico, and Utah, with freezing temperature at the higher elevations of Colorado and Utah; 8th, frost in Colorado, northern and eastern New Mexico, and freezing temperature in southwestern Colorado; 11th, frost in Colorado, northern and western New Mexico, and northwestern Utah, with freezing temperature in western Colorado, extreme northwestern New Mexico, and eastern Utah; 12th, frost in southern New Mexico, freezing temperature in western Colorado, northern New Mexico, and southern and eastern Utah; 13th, frost in northwestern Colorado, freezing temperature in southern and eastern Colorado; 18th, frost in northern Colorado; 30th, frost in southern New Mexico, south-central and southeastern Arizona, freezing temperature in Colorado and northern New Mexico; 31st, frost in south-central and southwestern New Mexico.

Warnings of freezing temperature in the valleys of western Colorado were issued on the 18th, 19th, 20th, 22d, 26th, 27th, 28th, and 30th. All frosts and freezing temperature warnings were generally [i. e., over most of the areas for which they were forecast] verified.

Fire-weather warnings, containing forecasts of strong winds in northern and western New Mexico, northern Arizona, and Utah were issued on the morning of the 29th to the district foresters at Albuquerque, N. Mex., and Ogden, Utah. Strong winds prevailed in the territory specified on the 29th and in Colorado on the 30th.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT

The month of October, 1924, opened in this district with a moderate storm passing eastward through British Columbia, which gave rain over the northern portion of the district during the first three days of the month. On the afternoon of the 4th a small depression moved inland through northern California and caused rain in California and Nevada on the 5th and 6th. On the 6th a moderate storm moved inland in the vicinity of Juneau and gave rain in the North Pacific States from the 7th to the 9th and in the northern Plateau on the 9th and 10th. On the 11th a storm appeared off Sitka and moved southeastward along the coast, giving rain in the western portions of Washington and Oregon from the 12th to the 15th, when it passed southeastward through the North Pacific States and central Plateau and caused rain on the 15th and 16th in northern California. On the 20th a large storm of marked energy appeared in the Gulf of Alaska, moving slowly southeast, and remained off the northern coast during the remainder of the month. It gave rain in the North Pacific States and on the extreme northwest California coast from the 23d to the end of the month, in northern California from the 26th to the 29th, and in Nevada and Idaho on the 28th and 29th.

The rain in the first decade practically ended all danger from forest fires for this season, which was one of the driest and worst for forest fires on record.

Storm warnings were displayed on the Washington and Oregon and Puget Sound on the 2d, 11th, 13th, 14th, 15th, 20th, 26th, and 28th to 31st; and on the northern California coast on the 14th, 15th, 20th, 26th, and 28th to 31st. The warnings were generally timely and verified. Very rough and stormy weather prevailed in the north Pacific during the third decade and one coast steamer was wrecked and several disabled. The *Acme* was wrecked near Bandon, Oreg.; the *Saginaw* and the *Trinidad* were disabled and towed to Astoria, and the *Yellowstone* lost a deckload of lumber and a mast but was able to make port at Eureka and the *Ocean Queen* was disabled off the Golden Gate and towed into San Francisco. No loss of life was reported.

Special forecasts were made for the dirigible airship *Shenandoah* during a flight from San Diego to Seattle and return. The forecasts were highly commended by the officer in charge. The flight was made during a lull between two storms, and it is believed that the advices given were in a great measure responsible for the successful voyage.—*G. H. Willson.*

RIVERS AND FLOODS

By H. E. FRANKENFIELD

Between September 28 and 30 heavy to excessive rains fell over the Middle and South Atlantic States, and from South Carolina northward except along the coast the tota fall was approximately from 4.50 to 6 inches. Floods followed quickly, of course, and they were general throughout the area covered by the heavy rains.

In the Hudson and Mohawk Rivers the flood was not severe, and the flood stage was reached at only one point, Troy, N. Y., where the crest stage was 0.5 foot above the flood stage of 15 feet between 9 and 10 p. m., October 1. That at Albany, N. Y., was 0.6 foot below the flood stage of 12 feet, two or three hours later. Warnings were issued in ample time to protect and save property and no damage was reported.

The Delaware River was not in flood except in the vicinity of Phillipsburg, N. J., where the flood stage of 22 feet was reached at 9 p. m. October 1. In this the Lehigh River was an important factor, as the flood stage of 12 feet at Mauch Chunk, Pa., was exceeded by 0.7 foot at 6 p. m. September 30, after a 24-hour rainfall of 5.51 inches. At Allentown, Pa., 30 miles below Mauch Chunk, the crest stage was 13.8 feet, 0.2 foot below the flood stage, at 11:10 p. m. September 30. The flood in the Schuylkill River paralleled that in the Lehigh in point of time, and at Reading, Pa., the crest stage was 16.6 feet, 6.6 feet above the flood stage, at 1 a. m. October 1. Warnings were issued on the morning of September 30, and were of great value to the enormous manufacturing industries along the Schuylkill. Some unavoidable damage resulted through wetting of goods and loss of time, but the losses were not great.

While floods were general in the North Branch of the Susquehanna River and its tributaries, the flood stages were not greatly exceeded, as the weather had been dry during the preceeding two weeks and the rivers were at the seasonal low stages. Warnings were issued promptly on the morning of September 30, but, nevertheless, the damage and loss at and above Binghamton, N. Y., almost entirely unavoidable, amounted to about $750,000. Crop losses reported aggregated $198,850, and those to buildings, highways, and bridges, $83,100. The value of property saved through the warnings did not exceed $15,000.

Flood stages did not extend very far below Wilkes-Barre, Pa., yet much damage was done, notwithstanding the warnings, and from the mouth of the Juniata to Harrisburg, Pa., the estimated losses were not less than $250,000, of which $50,000 was from loss of material at Clark's Ferry, at the mouth of the Juniata River, where a new bridge over the Susquehanna River is in course of construction.

There were no floods in the Potomac River drainage area, nor in the upper James River of Virginia. In the lower James there was a severe flood, beginning at Columbia at the mouth of the Rivanna River. At Columbia the crest stage was 31.3 feet, or 13.3 feet above the flood stage, at 9 a. m. October 1, following a rainfall of 4.63 inches, while at Richmond the crest stage was 19.4 feet, 9.4 feet above the flood stage, on the morning of October 2. Warnings were timely, but unavoidable losses in crops were considerable, and the damage to highways and bridges amounted to about $100,000. Losses occasioned by suspension of business amounted to $9,000, while the reported value of property saved through the flood warnings was $50,000.

The Roanoke River of Virginia and North Carolina and the other rivers of central and eastern North Carolina were in severe flood, the crests having been far above the flood stages, as much as 14 feet in portions of the Tar and Cape Fear Rivers. Warnings of severe floods were issued lon September 29 and 30, and all were well verified.

North Carolina floods seldom occur at this season of the year, and these were the greatest of record for the month of October. The total rainfall immediately preceding the floods was 10 inches or more, and only the dryness of the soil at the outset prevented still greater floods. As a rule the high waters continued during the first 10 days of October. Losses as reported were $205,500, of which $150,000 was in crops. Value of property saved through warnings, $147,000.

Floods in the rivers of South Carolina were also severe and the necessary warnings were issued on September 30. At Conway, S. C., on the Waccamaw River, the crest stage of 11.1 feet on October 9 and 10 was 4.1 feet above the flood stage and 0.9 foot above the previous high-water mark of September 7, 1908. The damage done along the Waccamaw River amounted to about $80,000 and the value of property saved through the warnings, $5,000. Along the Peedee River the loss and damage, exclusive of railroad losses, were about $50,000, and the value of property saved through the warnings $250,000. On the Black River damage to roads and bridges amounted to $3,000.

The Santee River had been in flood since September 17 and the heavy rains of the last three days of the month carried the river to much greater heights, Rimini, S. C., reporting a stage of 20.3 feet on October 4, or 8.3 feet above flood stage. The river remained above the flood stage until about October 18. The usual warnings were issued at the proper time. The losses reported were quite small, considering the severity of the floods, $25,750 in crops, $4,450 in livestock and other movable property, and $4,810 through enforced suspension of business. The value of property saved through the warnings was given as $52,700.

The floods in the Altamaha system of Georgia were only moderate, and no damage was reported. Warnings were issued as indicated.

Over the remainder of the country the usual low-water conditions incident to the season prevailed.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE					
Hudson:	*Feet*			*Feet*	
Troy, N. Y.	15	1	1	15.5	1
Delaware:					
Phillipsburg, N. J.	22	1	1	22.0	1
Lehigh:					
Mauch Chunk, Pa.	12	(1)	(2)	12.7	Sept. 30
Schuylkill:					
Reading, Pa.	10	(1)	1	16.6	1
Susquehanna:					
Bainbridge, N. Y.	11	1	2	[3]17.0	1
Binghamton, N. Y.	14	(1)	2	17.2	1
Towanda, Pa.	16	1	1	16.9	1
Wilkes-Barre, Pa.	20	1	2	22.4	1
Unadilla:					
New Berlin, N. Y.	8	1	1	8.6	1
Chenango:					
Sherburne, N. Y.	8	(1)	(2)	8.0	Sept. 30
James:					
Columbia, Va.	18	(1)	2	31.3	1
Richmond, Va.	10	1	3	19.4	2
Roanoke:					
Randolph, Va.	21	1	2	27.5	2
Weldon, N. C.	30	(1)	5	42.1	4

[1] Continued from last month.
[2] Below flood stage at 8 a. m., Oct. 1, 1924.
[3] Approximately.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE—continued					
Dan:	*Feet*			*Feet*	
Danville, Va	8	1	1	10.4	1
Clarksville, Va	12	2	3	12.5	2
Tar:					
Rocky Mount, N. C	9	(1)	5	15.0	1
Tarboro, N. C	18	1	9	32.3	4
Greenville, N. C	14	2	11	23.5	6
Fishing Creek:					
Enfield, N. C	15	(1)	3	17.3	1–2
Neuse:					
Neuse, N. C	15	(1)	5	20.7	2
Smithfield, N. C	14	(1)	7	24.0	1
Cape Fear:					
Fayetteville, N. C	35	(1)	4	49.6	2
Elizabethtown, N. C	22	(1)	7	33.8	3
Haw:					
Moncure, N. C	22	(1)	1	24.6	Sept. 30
Waccamaw:					
Conway, S. C	7	(1)	20	11.1	9–10
Peedee:					
Cheraw, S. C	27	1	4	34.7	2
Mars Bluff, S. C	17	1	11	21.9	6
Lynches:					
Effingham, S. C	14	6	6	14.4	6
Black:					
Kingstree, S. C	12	(1)	8	14.5	2
Santee:					
Rimini, S. C	12	(1)	13	20.3	4
Ferguson, S. C	12	(1)	18	15.2	6
Catawba:					
Catawba, S. C	12	(1)	1	18.3	1
Wateree:					
Camden, S. C	24	1	4	30.2	2
Congaree:					
Columbia, S. C	15	(1)	2	21.0	1
Broad:					
Blairs, S. C	15	(1)	2	24.0	1
Saluda:					
Pelzer, S. C	7	(1)	1	8.0	Sept. 30
Chappells, S. C	14	(1)	2	19.0	1
Oconee:					
Milledgeville, Ga	22	(1)	1	31.5	Sept. 26
Dublin, Ga	22	(1)	(2)	23.3	Sept. 30
		3	3	22.1	3
Ocmulgee:					
Macon, Ga	18	(1)	(2)	18.4	Sept. 30
Abbeville, Ga	11	1	9	12.4	6
MISSISSIPPI DRAINAGE					
Shenango:					
Sharon, Pa	9	(1)	2	9.4	1
Holston (North Fork):					
Mendota, Va	8	(1)	(2)	8.0	Sept. 30
PACIFIC DRAINAGE					
Willamette (Coast Fork):					
Saginaw, Oreg	9	31	(4)		

[1] Continued from last month.
[2] Below flood stage at 8 a. m., Oct. 1, 1924.
[3] Approximately.
[4] Continued at end of month.

MEAN LAKE LEVELS DURING OCTOBER, 1924

By UNITED STATES LAKE SURVEY

[Detroit, Mich., November 6, 1924]

The following data are reported in the "Notice to Mariners" of the above date:

Data	Lakes[1]			
	Superior	Michigan and Huron	Erie	Ontario
Mean level during October, 1924:	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	601.89	579.18	571.70	245.45
Above or below—				
Mean stage of September, 1924	0.00	−0.33	−0.25	−0.20
Mean stage of October, 1923	−0.11	−0.20	+0.47	+0.80
Average stage for October last 10 years	−0.72	−1.18	−0.35	−0.20
Highest recorded October stage	−1.75	−3.86	−2.00	−2.36
Lowest recorded October stage	+0.31	−0.20	+0.90	+1.78
Average relation of the October level to—				
September level		−0.25	−0.3	−0.4
November level		+0.2	+0.25	+0.20

[1] Lake St. Clair's level: In October, 1924, 574.38 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, OCTOBER, 1924

By J. B. KINCER

General summary.—Following the damaging frost which occurred in the Central-Northern States, including the upper Mississippi Valley, at the close of September, warm, sunshiny weather prevailed throughout the interior of the country, and was very favorable for maturing late crops and for farm work, especially for fall seeding. The unusually heavy rainfall during the first half of the month between the western upper Lake region and Rocky Mountains, while favorable in conditioning the soil for plowing and for fall-seeded grains, was somewhat unfavorable for farm work, especially for late threshing.

In much of the Atlantic coast area, where September was too wet for agricultural interests, the crop situation was markedly improved by the cessation of rainfall at the beginning of the month, and the period of dry, sunshiny weather which followed permitted rapid progress in field work, while late crops showed general improvement. It became too dry, however, in these sections the latter part of the month, though timely and beneficial showers occurred near the close. In central and west Gulf areas, where moisture had been deficient quite generally during much of the growing season, the persistent absence of material rainfall was unfavorable, and it was decidedly too dry for plowing and fall planting, while pastures were bare and stock water scarce.

In the Northwestern States farm work progressed under favorable weather conditions, with soil moisture mostly sufficient, though more rain was needed in the far Southwest. On the other hand, the agricultural outlook was greatly improved in central and northern Pacific coast districts by reason of better moisture conditions. In northern Plateau sections, light to moderate rains during the latter part of the month were very helpful, but in southern California it continued too dry.

Small grains.—During the first half of the month there was considerable interruption by rain to threshing in the Spring Wheat Belt, but elsewhere late threshing made good progress. Splendid weather prevailed for seeding winter wheat in the principal producing area, with the soil in good condition nearly everywhere, although in many parts of the Wheat Belt, more moisture was needed during the latter part of the month. It had also become too dry in the Southwest, where early seeded wheat made slow growth, and the late sown needed moisture for germination. Rains during the latter part of the month were very beneficial for this crop in the more northwestern States, especially in the eastern portions of Washington and Oregon, and in Idaho.

Corn.—Following the killing frost in the northwestern portion of the Corn Belt at the close of September, there was a reaction to much warmer weather, with very little rain and abundant sunshine, which conditions prevailed during most of October. The corn crop in the greater part of the large producing areas matured slowly and was very late in ripening and, while the frosted corn dried out well during the month, there was much complaint of chaffy ears and light yields. In most of the central valley States the first killing frost of the season was delayed until about the 25th of October, which permitted much corn to mature that would have been damaged if frost had occurred as early as in an average year.

Cotton.—The month in general was very favorable for the cotton crop. There was no frost of consequence in any part of the belt until the latter part of October, when the northern part had heavy to killing frost quite generally. The leaves of plants were rather widely killed at that time where the frost occurred, but there was no material damage to the crop, while in many places the frost was rather beneficial than harmful, inasmuch as it promoted rapid opening of bolls. Throughout the belt, practically the entire month had unusually favorable weather for picking and ginning, and nearly uninterrupted progress in this work was reported, with harvest well along at the close. In Georgia only scattered fields remained unpicked, and picking was nearly completed in Alabama, Mississippi, and Louisiana, as well as in eastern and southern Texas.

Miscellaneous.—Pastures and meadows in Central and Northern States continued in generally good condition until the latter part of the month, when dry weather was detrimental. Pastures in most of the Gulf area were badly dried and stock water scarce by reason of the long drought, but there was sufficient moisture in much of the great western grazing sections to be of material benefit. Potato harvest in Northern States made good progress, with the weather especially favorable for this work in the Northeast; reports of yields were generally satisfactory. There was considerable damage to truck crops in Florida by a tropical storm about the 20th of the month, but otherwise conditions were generally favorable for truck and minor crops in the Atlantic coast section. In other portions of the South it was too dry. Sugar cane in Louisiana was very poor and harvesting was delayed. The harvest of sugar beets progressed under generally favorable conditions, though in parts of Utah the soil was too dry.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, October, 1924

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal.	Station	Highest.	Date	Station	Lowest	Date.	Section average	Departure from the normal	Station	Amount	Station	Amount
	° F.	° F.		° F.			° F.		In.	In.		In.		In.
Alabama	65.1	−0.1	Selma	93	[2] 14	Saint Bernard	26	24	0.27	−2.56	Healing Springs	1.90	21 stations	0.00
Arizona	61.1	−0.7	Maricopa	109	1	5 stations	14	[2] 10	0.51	−0.40	2 stations	2.35	19 stations	0.00
Arkansas	64.9	+2.6	Searcy	96	12	Dutton	21	25	0.29	−2.71	Eureka Springs	2.13	2 stations	0.00
California	57.6	−3.2	2 stations	104	1	2 stations	10	[2] 11	2.93	+1.65	Crescent City	17.86	8 stations	0.00
Colorado	47.6	+1.2	Lamar	95	1	Crested Butte	−2	30	1.44	+0.20	Dillon	4.98	Buena Vista	0.04
Florida	71.7	−1.7	Fort Lauderdale	94	4	De Funiak Springs	37	24	10.82	+5.87	New Smyrna	39.08	Bluff Springs	0.25
Georgia	63.2	−1.6	Eatonton	90	[2] 19	Blue Ridge	22	24	1.32	−1.50	Saint George	4.45	Tallapoosa	0.29
Hawaii	73.3	−0.4	Waiauae	91	[2] 3	Waimea	51	24	10.30	+4.43	Eke	36.00	Puulua	0.00
Idaho	46.9	+0.5	2 stations	85	15	Idaho City	11	30	2.10	+0.67	Atlanta	5.34	Idaho Falls	0.47
Illinois	60.2	+5.0	Harrisburg	92	10	2 stations	21	23	0.97	−1.61	Clinton	3.39	Anna	T.
Indiana	59.4	+4.8	2 stations	90	[2] 9	3 stations	20	[2] 23	0.40	−2.30	South Bend	1.47	Vevay	0.00
Iowa	58.1	+6.2	Audubon	89	11	Fayette	21	22	0.87	−1.55	Mount Pleasant	2.58	Rockwell City	0.03
Kansas	60.9	+3.8	Cawker City	100	1	3 stations	19	31	1.27	−0.62	Arkansas City	3.28	Republic	0.25
Kentucky	61.2	+3.1	2 stations	91	[2] 5	2 stations	24	[2] 23	0.27	−2.33	Calhoun	1.39	4 stations	0.00
Louisiana	68.8	+0.9	Calhoun	98	5	Kelly (near)	27	26	0.12	−3.07	Delta Farms	2.07	21 stations	0.00
Maryland-Delaware	56.0	−0.4	Western Port, Md.	88	11	2 stations	15	23	0.40	−2.62	Cambridge, Md	1.78	2 stations	T.
Michigan	53.0	+4.1	Paw Paw	86	10	Vanderbilt (near)	12	22	0.49	−2.29	Eagle Harbor	2.73	Onaway (near)	0.06
Minnesota	53.0	+7.1	Beardsley	87	24	Red Lake	19	21	1.49	−0.55	Itasca State Park	4.66	Bird Island	0.02
Mississippi	66.7	+1.7	3 stations	94	[2] 4	Yazoo City	27	24	0.22	−2.44	Walnut Grove	2.00	13 stations	0.00
Missouri	61.8	+4.4	2 stations	92	[2] 8	Hollister	21	26	1.22	−1.53	Stover	4.17	3 stations	0.00
Montana	46.6	+2.5	Valentine	90	1	Wheaton	6	11	1.27	+0.20	Heron	3.58	2 stations	0.16
Nebraska	56.7	+5.6	Franklin	97	1	Harrison	21	31	0.99	−0.57	Haigler	2.90	Auburn	0.11
Nevada	50.5	−0.4	Beatty	98	2	Millett	10	[2] 12	1.02	+0.39	Owyhee	2.96	5 stations	0.00
New England	49.6	+0.7	Turner's Falls, Mass	88	11	2 stations	10	[2] 30	0.44	−3.06	Somerset, Vt	2.09	Turner's Falls, Mass	0.00
New Jersey	54.4	−0.4	Indian Mills	84	6	Runyon	16	23	0.31	−3.39	Little Falls	2.76	Phillipsburg	0.04
New Mexico	54.8	+1.3	Jal	95	13	3 stations	8	[2] 13	0.53	−0.79	Fort Sumner	2.90	7 stations	0.00
New York	50.0	−0.5	Jamestown	86	5	Gabriels	13	23	0.54	−2.93	Hoffmeister	2.71	2 stations	0.00
North Carolina	58.6	−1.5	Lumberton	89	18	Parker	15	[2] 22	1.11	−2.31	Southport	3.38	Bryson City	0.11
North Dakota	50.3	+6.5	West Hope	86	11	Jamestown	19	3	2.43	+1.43	Powers Lake	5.74	Washburn	0.97
Ohio	50.1	+2.2	Portsmouth	90	19	3 stations	20	23	0.26	−2.43	Norwalk	0.99	6 stations	0.00
Oklahoma	64.8	+3.3	Arapaho	98	4	Hooker	22	31	1.16	−1.77	Cheyenne	4.26	5 stations	0.00
Oregon	49.4	−0.4	Grants Pass	87	1	Fremont	3	11	4.61	+2.32	Willow Creek	19.31	Blitzen	0.32
Pennsylvania	52.9	+0.6	Indiana	87	9	Bradys Bend	14	23	0.28	−3.03	Hawley	2.30	6 stations	0.00
Porto Rico	78.3	+0.1	Dorado	99	22	Toro Negro	55	20	5.86	−2.45	Utuado	15.45	2 stations	1.41
South Carolina	62.2	−1.3	3 stations	89	[2] 7	Santuck	28	24	1.50	−1.49	Darlington	3.20	Calhoun Falls	0.56
South Dakota	54.6	+6.5	Tyndall	93	1	2 stations	20	[2] 26	1.31	+0.32	Vale	5.33	Hardy Ranger Station.	0.34
Tennessee	61.4	+1.6	Perryville	93	6	2 stations	21	23	0.34	−2.55	Greeneville	1.38	9 stations	T.
Texas	68.6	+1.1	2 stations	101	[2] 3	Romero	22	31	0.58	−2.04	Brownsville	5.12	35 stations	0.00
Utah	47.5	−1.2	Saint George	91	1	Loa	4	29	1.34	−0.01	Silver Lake	3.35	Escalanti	0.00
Virginia	56.8	−0.9	Leeds Manor	88	8	Burkes Garden	14	22	1.14	−1.97	Urbanna	3.48	Hot Springs	0.05
Washington	50.0	+0.3	Wapato	84	17	Snyders Ranch	16	10	3.93	+1.04	Forks	23.78	Ellensburg	0.15
West Virginia	54.6	−0.2	3 stations	87	[2] 6	Cheat Bridge	14	23	0.40	−2.56	Harpers Ferry	1.28	Morgantown	0.07
Wisconsin	53.7	+5.5	Richland Center	84	19	Minocqua	12	22	0.59	−2.07	Cornucopia	2.36	2 stations	T.
Wyoming	45.6	+2.1	2 stations	83	[2] 1	Dixon	6	10	2.13	+1.04	Moran	5.20	Deaver	0.14

[1] For description of tables and charts, see REVIEW, January, 1924, pp 56–57.

[2] Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, October, 1924*

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + 2 mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F*		*°F*	*°F.*		*°F*	*°F.*	*°F.*	*°F.*	*%*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England							**51.3**	**+0.3**										**72**	**0.22**	**−3.4**										**3.6**		
Eastport	76	67	85	29.97	30.05	+0.05	48.1	+0.6	67	25	55	31	21	41	25	43	39	77	1.14	−2.7	7	7,721	nw.	43	se.	1	13	6	12	5.0	T.	0.0
Greenville, Me	1,070	6	----	28.93	30.11	------	46.5	------	74	6	56	18	31	37	38	----	----	----	1.33	------	7	------	nw.	----	----	----	17	5	9	----	0.5	0.0
Portland, Me	103	82	117	30.02	30.14	+.10	51.6	+1.7	80	6	60	30	31	43	31	44	38	65	0.09	−3.6	2	6,448	nw.	37	s.	1	19	8	4	3.0	T.	0.0
Concord	288	70	79	29.83	30.15	+.10	49.0	−0.7	79	6	62	18	31	36	38	----	----	----	0.05	−3.2	1	3,483	nw.	23	nw.	20	20	7	4	3.2	0.0	0.0
Burlington	404	11	48	29.73	30.18	+.14	48.4	−0.8	72	3	57	26	30	40	30	----	----	----	0.15	−3.0	2	7,315	s.	39	s.	31	12	11	8	4.5	T.	0.0
Northfield	876	12	60	29.22	30.20	+.16	45.1	−0.4	75	5	58	20	31	32	37	39	37	84	0.08	−2.4	4	4,934	s.	26	nw.	19	16	8	7	4.2	0.4	0.0
Boston	125	115	188	30.01	30.15	+.10	54.6	+1.0	81	6	63	36	21	46	27	47	41	66	0.06	−3.8	2	6,762	w.	26	w.	1	17	11	3	6.7	0.0	0.0
Nantucket	12	14	90	30.11	30.12	+.07	53.6	−0.6	71	28	60	37	31	47	21	49	46	79	0.10	−3.3	3	11,414	n.	48	n.	10	17	10	4	3.3	0.0	0.0
Block Island	26	11	46	30.12	30.14	+.09	54.0	−0.9	67	28	60	39	31	48	16	48	44	71	0.23	−3.9	2	12,272	nw.	46	nw.	12	20	5	6	2.8	0.0	0.0
Providence	160	215	251	29.97	30.15	+.10	53.2	+1.0	80	6	63	30	31	44	26	45	39	63	0.15	−3.7	2	8,039	nw.	37	nw.	19	22	7	2	2.4	0.0	0.0
Hartford	159	122	140	30.00	30.17	+.11	53.1	+1.9	80	6	64	30	31	42	34	----	----	----	0.18	−3.7	2	------	nw.	----	----	----	24	6	1	2.1	0.0	0.0
New Haven	106	74	153	30.05	30.17	+.11	53.8	0.0	78	6	64	32	21	44	27	47	42	69	0.23	−3.7	2	6,191	n.	30	ne.	10	21	10	0	2.5	0.0	0.0
Middle Atlantic States							**56.4**	**0.0**										**71**	**0.44**	**−2.8**										**2.8**		
Albany	97	102	115	30.08	30.19	+.13	51.6	−0.5	76	6	62	30	23	41	30	45	40	74	0.09	−2.9	2	4,432	s.	27	s.	31	16	12	3	3.3	0.0	0.0
Binghamton	871	10	84	29.26	30.20	+.14	49.8	−0.2	79	5	62	28	18	38	36	----	----	----	0.44	−2.7	2	3,041	nw.	18	w.	1	15	10	6	4.2	T.	0.0
New York	314	414	454	29.85	30.19	+.13	56.8	+0.5	78	6	65	36	23	49	24	48	40	60	0.30	−3.4	2	10,645	n.	48	nw.	20	18	9	4	3.3	0.0	0.0
Harrisburg	374	94	104	29.82	30.23	+.15	56.0	+1.2	80	6	66	37	14	46	32	47	41	64	0.02	−2.9	2	3,941	nw.	27	ne.	12	19	7	5	3.2	0.0	0.0
Philadelphia	114	123	190	30.08	30.21	+.14	58.6	+0.8	80	6	68	37	23	49	25	49	41	58	0.09	−3.0	2	6,245	n.	35	n.	20	18	8	5	3.5	0.0	0.0
Reading	325	81	98	29.86	30.22	------	56.3	------	80	6	68	35	23	45	33	48	44	70	0.04	−3.2	1	3,183	nw.	19	w.	1	24	5	2	2.3	0.0	0.0
Scranton	805	111	119	29.36	30.23	+.16	51.8	−0.1	78	6	64	31	18	40	35	46	44	85	0.08	−2.8	1	4,078	n.	25	sw.	1	18	8	5	3.9	T.	0.0
Atlantic City	52	37	172	30.13	30.19	+.12	56.7	−0.2	74	12	65	35	22	48	29	51	46	72	0.05	−3.2	1	10,371	nw.	39	n.	20	23	6	2	1.9	0.0	0.0
Cape May	17	13	49	30.20	30.22	+.15	58.4	−1.2	77	17	67	35	23	50	26	52	49	80	0.69	−2.6	2	4,561	n.	17	nw.	1	24	4	3	2.2	0.0	0.0
Sandy Hook	22	10	55	30.16	30.18	------	56.9	------	76	6	64	40	21	50	22	50	44	68	0.17	------	1	9,587	nw.	46	nw.	20	20	10	1	2.8	0.0	0.0
Trenton	190	159	183	29.99	30.19	------	56.2	------	79	6	67	34	23	46	30	48	42	66	0.20	−3.2	1	6,402	n.	36	n.	20	19	10	2	3.2	0.0	0.0
Baltimore	123	100	113	30.07	30.20	+.12	59.4	+1.2	84	6	69	36	23	50	28	51	44	64	0.05	−3.0	2	3,306	n.	20	n.	8	23	2	6	2.8	0.0	0.0
Washington	112	62	85	30.09	30.21	+.13	57.4	0.0	83	6	69	34	23	46	33	49	45	71	0.44	−2.6	2	3,442	nw.	20	n.	21	22	5	4	2.7	0.0	0.0
Cape Henry	18	8	54	30.16	30.18	------	60.2	------	80	7	66	45	25	54	24	56	53	81	0.45	−3.4	3	8,797	n.	42	ne.	21	22	5	4	2.4	0.0	0.0
Lynchburg	681	153	188	29.47	30.22	+.13	58.4	−0.1	86	6	72	28	22	44	39	49	46	75	2.48	−0.9	3	3,116	nw.	30	e.	27	23	6	2	2.4	0.0	0.0
Norfolk	91	170	205	30.10	30.20	+.13	62.0	−0.5	83	7	70	45	25	54	27	54	50	74	0.11	−3.8	3	7,213	ne.	31	ne.	21	21	7	3	2.6	0.0	0.0
Richmond	144	11	52	30.06	30.21	+.13	58.6	−1.0	83	7	71	34	22	46	34	51	47	74	0.78	−2.5	2	4,079	ne.	21	ne.	27	25	2	4	2.4	0.0	0.0
Wytheville	2,304	49	55	27.85	30.26	+.17	54.1	−0.5	80	7	68	25	22	40	40	46	42	78	1.23	−1.9	2	2,814	nw.	16	sw.	20	27	1	3	2.0	0.0	0.0
South Atlantic States							**62.8**	**−1.5**										**75**	**1.94**	**−1.7**										**3.2**		
Asheville	2,255	70	84	27.87	30.25	+.16	55.8	+0.5	78	7	69	27	23	42	36	48	44	75	1.21	−1.3	4	3,823	nw.	24	se.	8	22	5	4	2.7	0.0	0.0
Charlotte	779	55	62	29.36	30.21	+.13	60.9	−0.8	82	19	72	36	22	50	28	52	47	66	0.45	−2.7	2	2,651	ne.	15	ne.	21	26	1	4	1.9	0.0	0.0
Hatteras	11	11	50	30.15	30.16	+.10	63.2	−2.7	79	8	69	50	22	58	17	58	55	78	1.03	−5.0	2	9,563	n.	37	n.	21	19	7	5	3.6	0.0	0.0
Manteo	12	5	42	----	----	----	59.3	------	84	19	---	36	25	---	34	----	----	----	0.50	------	2	------	ne.	----	----	----	18	7	6	----	0.0	0.0
Raleigh	376	103	110	29.80	30.20	+.13	60.8	−1.2	83	19	71	36	22	50	27	52	48	70	1.28	−2.2	2	4,639	ne.	24	ne.	21	24	4	3	2.2	0.0	0.0
Wilmington	78	81	91	30.10	30.19	+.13	62.9	−2.4	82	19	73	39	22	53	26	56	53	78	0.90	−2.8	1	4,535	n.	22	ne.	26	20	6	5	3.1	0.0	0.0
Charleston	48	11	92	30.10	30.15	+.09	65.8	−2.0	81	6	72	45	22	59	20	60	57	81	1.66	−2.3	2	9,014	ne.	36	ne.	26	16	4	11	4.6	0.0	0.0
Columbia, S. C	351	41	57	29.81	30.20	+.13	62.6	−1.7	84	20	73	39	24	52	31	55	50	73	1.18	−1.7	3	3,962	ne.	24	ne.	21	26	1	4	2.5	0.0	0.0
Due West	711	10	55	29.45	30.23	------	60.8	------	83	20	72	37	23	50	30	----	----	----	0.97	------	3	5,280	ne.	29	ne.	26	25	3	3	2.0	0.0	0.0
Greenville, S. C	1,039	113	122	29.09	30.19	------	61.5	+1.3	83	20	72	38	22	51	29	53	48	67	0.85	------	2	4,295	ne.	22	n.	26	24	4	3	1.9	0.0	0.0
Augusta	180	62	77	29.98	30.17	+.10	63.2	−2.1	86	20	75	39	24	52	35	55	52	77	1.91	−0.4	3	3,286	ne.	20	ne.	21	23	5	3	2.6	0.0	0.0
Savannah	65	150	194	30.07	30.14	+.09	65.2	−2.7	80	6	73	45	23	58	21	59	56	80	1.74	−1.8	5	8,610	ne.	30	ne.	9	13	6	12	5.1	0.0	0.0
Jacksonville	43	209	245	30.03	30.08	+.06	68.4	−2.7	80	5	74	47	23	63	19	64	62	84	8.08	+3.0	10	10,640	ne.	40	ne.	21	6	8	17	6.6	0.0	0.0
Florida Peninsula							**75.8**	**−1.2**										**81**	**14.27**	**+8.5**										**6.4**		
Key West	22	10	64	29.88	29.90	−.04	78.2	−0.9	88	9	83	70	18	74	15	73	72	83	12.55	+7.2	18	9,830	ne.	66	sw.	30	9	8	14	6.1	0.0	0.0
Miami	25	71	79	29.91	29.94	------	76.8	−1.0	86	11	82	67	22	72	14	72	70	81	25.02	+16.1	26	7,808	e.	34	nw.	21	4	10	17	7.2	0.0	0.0
Sand Key	23	39	72	29.88	29.91	−.03	77.8	------	89	11	81	71	18	75	10	73	71	80	14.97	------	16	15,220	ne.	64	sw.	20	6	11	14	6.0	0.0	0.0
Tampa	35	79	87	29.96	30.00	+.02	72.5	−1.8	88	9	80	56	23	65	23	66	64	81	5.25	+2.3	12	7,091	ne.	30	ne.	20	9	8	14	6.2	0.0	0.0
East Gulf States							**66.2**	**0.0**										**68**	**0.49**	**−2.3**										**2.8**		
Atlanta	1,174	190	216	28.95	30.19	+.12	63.4	+0.4	82	20	73	40	1	54	24	54	48	64	0.90	−1.4	1	6,776	e.	27	nw.	28	25	3	3	2.2	0.0	0.0
Macon	370	78	87	29.77	30.17	+.11	62.2	−2.3	83	19	74	37	24	51	33	54	50	74	0.75	−1.4	2	4,667	ne.	20	ne.	9	21	4	6	2.6	0.0	0.0
Thomasville	273	49	58	29.81	30.10	+.04	66.3	−1.9	83	14	76	42	23	57	28	58	54	74	2.05	−1.4	4	4,029	ne.	16	ne.	18	14	4	13	5.0	0.0	0.0
Apalachicola	36	42	49	30.03	30.07	------	67.6	------	82	21	74	48	23	61	24	61	58	78	1.82	------	4	9,262	ne.	31	ne.	20	17	6	8	4.1	0.0	0.0
Pensacola	56	149	185	30.04	30.10	+.07	68.6	−1.3	84	20	76	49	24	61	24	61	56	68	0.49	−3.6	5	9,634	e.	40	se.	5	20	4	7	3.0	0.0	0.0
Anniston	741	9	57	29.41	30.22	+.15	62.9	+0.5	84	20	77	31	24	49	39	----	----	----	0.02	−2.3	1	2,764	se.	16	s.	3	24	5	2	1.6	0.0	0.0
Birmingham	700	11	48	29.42	30.18	+.11	66.6	+1.8	88	8	79	38	24	54	32	53	45	56	0.00	−2.3	0	4,072	e.	19	se.	4	25	3	3	1.8	0.0	0.0
Mobile	57	125	161	30.04	30.10	+.06	68.4	+1.0	86	5	79	44	24	58	31	59	55	71	0.31	−2.9	3	6,398	ne.	25	e.	9	18	8	5	3.7	0.0	0.0
Montgomery	223	100	112	29.90	30.16	+.10	65.5	−1.1	84	20	77	40	24	54	31	55	48	61	0.25	−2.2	2	4,173	ne.	20	e.	22	25	3	3	1.8	0.0	0.0
Cornith	469	6	----	----	----	----	64.9	------	89	5	81	32	24	49	42	----	----	----	0.00	------	0	------	ne.	----	----	----	19	12	0	----	0.0	0.0
Meridian	375	85	93	29.74	30.14	+.08	64.4	+0.1	84	19	78	34	24	51	35	55	50	68	0.39	−2.3	2	3,221	ne.	18	e.	9	24	5	2	2.1	0.0	0.0
Vicksburg	247	65	73	29.87	30.15	+.09	68.3	+1.6	88	5	80	38	23	57	32	57	50	62	0.19	−2.6	1	4,149	e.	16	e.	9	25	5	1	2.1	0.0	0.0
New Orleans	53	76	84	30.03	30.08	+.05	72.0	+1.0	87	4	79	52	24	65	23	62	57	69	T.	−2.9	0	5,590	e.	24	e.	12	21	6	4	3.1	0.0	0.0
West Gulf States							**70.2**	**+2.3**										**68**	**0.26**	**−2.5**										**2.1**		
Shreveport	249	77	93	29.84	30.11	+.06	69.4	+2.8	88	4	82	40	25	57	32	57	50	59	T.	−3.2	0	3,923	ne.	23	s.	30	29	2	0	1.1	0.0	0.0
Bentonville	1,303	11	44	----	----	----	62.3	+4.3	84	6	76	31	24	49	39	----	----	----	1.42	------	4	3,067	s.	29	s.	30	28	2	1	----	0.0	0.0
Fort Smith	457	79	94	29.63	30.11	+.06	66.6	+3.8	87	6	80	37	26	54	36	56	50	65	1.08	−1.8	3	4,961	e.	37	nw.	30	22	7	2	2.4	0.0	0.0
Little Rock	357	136	144	29.76	30.13	+.07	67.2	+3.6	88	5	79	41	23	56	31	56	49	60	0.06	−2.5	1	4,753	e.	34	s.	30	21	10	0	2.0	0.0	0.0
Brownsville	57	4	26	29.95	30.01	------	74.9	0.0	89	9	83	53	24	67	22	68	66	83	5.12	------	9	4,502	n.	24	ne.	13	17	10	4	3.6	0.0	0.0
Corpus Christi	20	11	73	30.03	30.05	+.05	74.4	+1.2	88	13	81	52	26	68	22	69	67	84	0.25	−1.8	4	8,159	e.	27	ne.	14	23	5	3	2.5	0.0	0.0
Dallas	512	109	117	29.55	30.10	------	69.2	------	89	4	81	38	26	58	34	----	----	----	0.13	------	1	5,242	se.	39	s.	30	25	5	1	1.8	0.0	0.0
Fort Worth	670	106	114	29.35	30.06	+.03	69.4	+2.7	90	4	81	38	26	58	34	57	49	56	T.	−2.5	0	6,010	e.	37	s.	30	23	7	1	1.8	0.0	0.0
Galveston	54	106	114	30.02	30.08	+.05	73.7	+1.0	85	20	79	52	25	68	19	66	62	74	0.03	−4.2	1	6,785	se.	25	ne.	13	25	6	0	1.3	0.0	0.0
Groesbeck	461	11	56	29.60	30.08	------	68.6	------	91	4	82	35	27	51	40	----	----	----	0.17	------	2	5,853	ne.	35	s.	5	24	6	1	1.9	0.0	0.0
Houston	138	111	121	29.93	30.08	------	72.9	+2.6	90	4	83	45	25	62	28	----	----	----	0.44	------	2	4,725	se.	23	se.	7	17	13	1	3.3	0.0	0.0
Palestine	510	64	72	29.57	30.10	+.07	69.6	+2.4	90	5	81	42	24	58	31	58	51	59	0.30	−3.3	1	4,738	ne.	24	sw.	30	24	6	1	2.0	0.0	0.0
Port Arthur	34	58	66	30.03	30.07	------	71.9	------	86	4	81	45	25	63	29	63	59	73	0.00	------	0	5,743	ne.	22	se..	30	25	6	0	1.7	0.0	0.0
San Antonio	693	119	132	29.34	30.06	+.05	72.0	+1.5	91	5	83	45	26	61	29	61	55	64	0.52	−1.0	5	4,844	e.	26	ne.	21	22	6	3	2.3	0.0	0.0
Taylor	583	55	63	29.50	30.11	+.09	70.4	+2.1	91	4	82	41	26	58	34	----	----	----	0.06	−2.5	2	4,966	ne.	27	s.	30	23	5	3	2.1	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, October, 1924*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. +½ mean min.	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F*		*° F*	*° F.*		*° F*	*° F.*	*° F.*	*° F.*	*%*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							60.5	+2.8										67	0.26	−2.3											2.9		
Chattanooga	762	189	213	29.39	30.21	+.12	62.4	+0.5	84	7	74	39	1	50	33	52	47	65	0.22	−2.6	1	3,326	n.	25	n.	21	20	9	2	2.5	0.0	0.0
Knoxville	996	102	111	29.14	30.21	+.15	60.4	+0.5	82	8	72	34	23	48	31	52	49	75	0.99	−1.6	2	3,008	ne.	21	n.	21	19	4	8	3.3	0.0	0.0
Memphis	399	76	97	29.73	30.16	+.09	67.2	+3.9	87	7	77	40	23	57	27	56	48	58	0.09	−2.6	1	3,729	ne.	19	nw.	31	26	5	0	1.4	0.0	0.0
Nashville	546	168	191	29.62	30.21	+.13	63.6	+2.6	84	18	76	36	24	51	34	53	46	62	0.03	−2.4	2	5,275	ne.	29	ne.	22	23	6	2	2.3	0.0	0.0
Lexington	989	193	230	29.16	30.23	+.15	62.4	+5.0	80	15	72	34	23	53	28	----	----	----	0.11	−2.0	2	8,153	ne.	36	sw.	31	21	4	6	3.0	0.0	0.0
Louisville	525	188	234	29.64	30.22	+.14	62.3	+3.0	82	12	74	35	23	51	31	52	46	62	0.10	−2.5	1	5,862	n.	30	s.	31	23	6	2	2.3	0.0	0.0
Evansville	431	139	175	29.74	30.20	+.12	65.0	+5.6	86	9	76	35	22	53	30	53	46	57	0.15	−3.0	1	6,502	ne.	36	sw.	30	19	11	1	2.9	0.0	0.0
Indianapolis	822	194	230	29.33	30.22	+.15	61.0	+5.3	82	11	72	33	23	50	28	52	46	64	0.79	−2.0	3	6,802	ne.	36	w.	31	21	7	3	2.5	0.0	0.0
Royal Center	736	11	55	29.41	30.22	------	57.2	------	82	10	71	22	23	44	39	----	----	----	0.61	------	3	5,320	s.	33	w.	31	18	8	5	3.4	0.0	0.0
Terre Haute	575	96	129	29.58	30.20	------	61.4	------	85	10	74	32	23	49	33	51	45	65	0.55	------	3	5,832	n.	35	s.	30	21	7	3	2.7	0.0	0.0
Cincinnati	628	11	51	29.55	30.23	+.15	59.4	+3.7	83	19	73	30	23	46	38	----	46	68	0.17	−2.2	1	3,849	ne.	22	ne.	20	23	4	4	2.3	0.0	0.0
Columbus	824	179	222	29.36	30.24	+.16	58.7	+3.5	80	19	70	32	23	48	31	50	44	67	0.10	−2.2	2	5,878	e.	30	n.	20	22	3	6	2.5	0.0	0.0
Dayton	899	137	173	29.26	30.22	------	59.0	+4.0	82	19	72	32	23	46	35	49	43	65	0.33	−2.1	3	4,846	ne.	28	sw.	31	21	7	3	2.6	0.0	0.0
Elkins	1,947	59	67	28.19	30.29	+.19	52.2	−0.1	79	3	67	24	24	37	44	43	41	85	0.26	−2.2	3	2,230	nw.	22	nw.	31	14	9	8	4.8	0.0	0.0
Parkersburg	638	77	84	29.60	30.26	+.18	57.6	+1.5	81	5	71	30	24	44	38	48	44	75	0.25	−2.2	2	2,039	se.	22	nw.	31	21	6	4	3.8	0.0	0.0
Pittsburgh	842	353	410	29.33	30.25	+.17	56.4	+0.7	80	3	68	31	23	45	35	48	43	70	0.12	−2.2	3	5,177	nw.	34	nw.	31	14	13	4	3.9	0.0	0.0
Lower Lake Region							54.0	+1.9										71	0.39	−2.6										3.8		
Buffalo	767	247	280	29.39	30.23	+.18	52.7	+0.8	79	3	59	36	21	46	26	48	45	78	0.08	−3.4	2	9,834	sw.	62	w.	1	12	13	6	4.7	T.	0.0
Canton	448	10	61	29.70	30.18	------	47.3	+0.1	77	3	58	26	13	37	34	----	----	----	0.65	−2.7	5	6,528	sw.	44	w.	1	20	6	5	3.4	T.	0.0
Oswego	335	76	91	------	30.19	+.14	50.4	−0.8	76	5	59	32	18	42	27	----	----	75	0.18	−3.2	5	6,386	sw.	30	n.	21	14	8	9	----	T.	0.0
Rochester	523	86	102	29.65	30.23	+.18	51.9	+0.4	79	3	61	32	23	43	30	45	41	72	0.08	−2.8	3	4,712	sw.	38	w.	1	10	12	9	4.8	T.	0.0
Syracuse	597	97	113	29.57	30.22	+.16	51.5	+0.5	77	5	60	33	18	43	27	----	----	----	0.39	−2.8	5	6,096	s.	36	sw.	1	14	10	7	4.3	T.	0.0
Erie	714	130	166	29.45	30.22	+.17	54.6	+1.2	80	3	63	34	23	47	27	48	44	72	0.02	−3.8	2	8,670	w.	48	se.	31	16	12	3	3.3	T.	0.0
Cleveland	762	190	201	29.40	30.24	+.18	55.6	+2.0	79	5	64	35	23	48	32	49	43	68	0.68	−2.0	4	7,926	s.	40	n.	20	14	10	7	4.2	0.0	0.0
Sandusky	629	62	70	29.55	30.24	+.18	56.8	+2.5	80	5	65	36	23	49	31	----	----	----	0.64	−1.8	6	4,616	s.	21	n.	21	12	12	7	4.5	0.0	0.0
Toledo	628	208	243	29.54	30.24	+.19	57.8	+4.4	78	5	67	35	22	49	31	49	43	67	0.74	−1.5	4	8,396	sw.	44	sw.	31	21	7	3	2.6	0.0	0.0
Fort Wayne	856	113	124	29.30	30.23	------	58.1	+4.4	81	11	70	31	22	47	34	50	44	69	0.34	------	4	4,773	sw.	25	sw.	5	20	8	3	3.0	0.0	0.0
Detroit	730	218	258	29.44	30.24	+.19	57.4	+4.9	77	5	66	35	22	48	26	48	42	66	0.47	−1.9	3	6,504	nw.	40	sw.	31	18	9	4	3.4	0.0	0.0
Upper Lake Region							53.6	+5.0										76	0.80	−2.3										3.7		
Alpena	609	13	92	29.53	30.20	+.17	51.4	+4.3	75	5	60	29	22	43	33	45	42	80	0.35	−3.1	3	7,935	se.	38	sw.	31	12	16	3	4.0	0.0	0.0
Escanaba	612	54	60	29.49	30.16	+.15	50.6	+4.6	69	5	59	27	22	42	31	46	42	79	0.07	−3.0	3	6,933	s.	32	s.	31	19	7	5	3.5	0.0	0.0
Grand Haven	632	54	89	29.50	30.19	+.16	54.0	+3.3	76	30	63	28	22	45	32	48	44	77	0.20	−2.3	7	7,270	s.	36	sw.	31	20	10	1	3.3	0.0	0.0
Grand Rapids	707	70	87	29.44	30.22	+.18	56.4	+6.2	77	11	68	30	22	45	32	48	43	71	0.23	−2.3	3	3,203	s.	23	w.	31	14	12	5	3.8	0.0	0.0
Houghton	668	62	99	29.37	30.10	+.10	52.1	+6.4	80	2	61	33	22	43	34	----	----	----	1.78	−1.4	7	6,303	e.	52	w.	31	14	7	10	4.9	0.0	0.0
Lansing	878	11	62	29.26	30.22	------	54.6	+4.3	79	10	68	25	23	41	38	45	41	77	0.30	−1.9	2	3,391	s.	21	sw.	31	19	11	1	2.7	0.0	0.0
Ludington	637	60	66	29.48	30.18	------	53.4	------	75	30	61	32	22	46	30	48	44	77	0.07	------	2	7,480	s.	45	sw.	31	22	8	1	2.5	0.0	0.0
Marquette	734	77	111	29.34	30.16	+.15	53.0	+6.3	76	13	62	33	1	44	32	46	42	74	0.34	−2.8	2	7,439	s.	36	s.	9	10	10	11	5.4	0.0	0.0
Port Huron	638	70	120	29.51	30.21	+.17	54.0	+3.5	75	5	64	33	23	44	29	47	43	75	0.32	−2.4	4	7,370	s.	34	w.	31	14	16	1	3.3	T.	0.0
Saginaw	641	69	77	29.51	30.22	------	54.1	+3.8	76	3	66	30	23	43	33	47	42	75	0.38	−2.4	5	5,338	sw.	32	sw.	31	16	11	4	3.8	0.0	0.0
Sault Sainte Marie	614	11	52	29.48	30.19	+.18	49.4	+4.8	74	3	58	27	22	40	31	44	41	84	0.38	−2.9	5	5,424	se.	36	sw.	31	12	13	6	4.6	0.0	0.0
Chicago	823	140	310	29.30	30.20	+.16	59.8	+4.7	81	19	67	40	23	53	27	52	46	65	0.84	−1.7	4	8,548	s.	42	s.	30	23	4	4	2.8	0.0	0.0
Green Bay	617	109	144	29.47	30.14	+.12	54.0	+5.5	76	13	63	30	22	45	30	47	42	74	0.08	−2.3	4	7,424	s.	42	sw.	31	15	12	4	3.9	0.0	0.0
Milwaukee	681	125	139	29.43	30.17	+.14	56.2	+5.1	76	13	64	36	22	48	29	49	45	72	0.09	−2.3	4	7,095	sw.	36	sw.	31	19	7	5	3.8	0.0	0.0
Duluth	1,133	5	47	28.84	30.08	+.08	50.8	+6.7	71	26	59	30	21	42	29	44	41	79	1.63	−1.1	8	8,771	ne.	52	nw.	31	17	7	7	3.9	0.0	0.0
North Dakota							51.5	+8.2										74	2.22	+0.9										4.1		
Moorhead	940	50	58	28.95	29.98	−.02	53.1	+8.6	79	17	64	32	10	42	36	46	42	75	2.87	+0.8	6	6,673	s.	31	sw.	12	20	5	6	3.6	0.0	0.0
Bismarck	1,674	8	57	28.18	29.97	−.02	53.0	+8.1	76	25	66	33	3	40	40	45	40	71	2.02	+1.0	5	7,328	se.	44	sw.	12	14	5	12	4.9	0.0	0.0
Devils Lake	1,478	11	44	28.36	29.94	−.05	50.4	+9.9	78	26	62	31	7	39	33	43	40	79	2.08	+0.8	8	7,366	se.	38	sw.	12	17	3	11	4.1	0.0	0.0
Ellendale	1,457	10	56	28.40	29.97	------	52.3	------	78	1	66	29	28	39	41	----	----	----	1.35	------	5	10,582	s.	49	nw.	5	17	3	11	4.2	0.0	0.0
Grand Forks	835	12	89	------	------	------	50.8	------	75	26	62	30	7	39	40	44	----	----	2.46	------	6	------	s.	54	s.	12	18	4	9	----	T.	0.0
Williston	1,878	41	48	27.93	29.92	−.06	49.4	+6.0	75	26	62	29	6	37	37	42	37	71	1.90	+1.1	6	5,738	sw.	48	w.	12	18	5	8	3.6	4.5	0.0
Upper Mississippi Valley							59.4	+6.3										70	1.07	−1.3										3.2		
Minneapolis	918	102	208	29.05	30.04	------	56.6	+7.7	79	11	66	35	21	47	29	----	----	----	0.76	−1.8	7	8,430	se.	36	nw.	31	14	5	12	4.8	0.0	0.0
St. Paul	837	236	261	29.15	30.05	+.04	55.8	+7.2	78	11	66	35	21	46	28	----	----	----	0.76	−1.6	7	9,073	se.	44	s.	30	14	10	7	4.2	0.0	0.0
La Crosse	714	11	48	29.35	30.12	+.10	56.7	+6.4	81	12	68	28	22	45	31	----	----	----	0.75	−1.7	8	3,664	se.	26	sw.	30	16	11	4	3.7	0.0	0.0
Madison	974	70	78	29.12	30.17	+.14	56.6	+6.3	78	12	67	34	22	46	32	48	42	68	0.22	−2.2	5	5,905	s.	30	s.	30	15	11	5	3.7	0.0	0.0
Wausau	1,247	4	----	28.78	30.16	------	52.6	------	75	12	64	25	22	42	35	----	----	----	0.40	------	5	------	s.	----	----	----	19	7	5	3.4	0.0	0.0
Charles City	1,015	10	49	29.03	30.12	+.10	56.2	+8.0	83	18	69	28	22	44	33	47	43	75	1.24	−0.8	7	4,794	se.	30	sw.	30	20	8	3	2.8	0.0	0.0
Davenport	606	71	79	29.49	30.16	+.12	60.0	+6.3	83	11	71	31	23	48	33	51	46	70	0.86	−1.5	8	4,449	s.	30	w.	30	25	2	4	2.3	0.0	0.0
Des Moines	861	84	97	29.18	30.10	+.07	59.6	+6.2	83	19	71	33	23	48	32	51	45	68	0.77	−1.9	6	5,191	sw.	40	sw.	30	16	7	8	4.1	0.0	0.0
Dubuque	700	81	96	29.38	30.13	+.09	57.5	+5.6	83	18	69	28	22	46	34	48	44	70	0.43	−2.2	5	3,801	s.	24	se.	30	17	7	7	3.9	0.0	0.0
Keokuk	614	64	78	29.47	30.15	+.10	61.4	+6.0	85	18	73	33	23	50	35	52	46	68	1.66	−0.8	5	4,572	s.	35	s.	30	21	3	7	2.8	0.0	0.0
Cairo	358	87	93	29.78	30.17	+.10	65.3	+4.9	86	19	77	38	23	54	28	55	51	71	0.14	−2.5	2	4,596	n.	28	s.	30	19	9	3	2.8	0.0	0.0
Peoria	609	11	45	29.52	30.19	+.14	59.2	+7.2	84	18	72	28	23	46	38	51	47	78	1.27	−1.3	6	3,760	s.	33	w.	30	26	3	2	1.4	0.0	0.0
Springfield, Ill.	636	10	91	29.48	30.16	+.11	61.6	+5.2	82	10	72	34	23	50	30	52	47	70	3.02	+0.4	6	4,848	s.	28	s.	30	22	6	3	2.6	0.0	0.0
Hannibal	534	74	109	29.59	30.16	+.11	60.8	+4.8	86	18	74	30	23	47	40	----	----	----	2.80	+1.2	7	5,267	s.	34	w.	30	22	5	4	2.5	0.0	0.0
St. Louis	568	265	303	29.55	30.16	+.10	64.6	+6.2	85	18	74	37	22	55	27	54	47	59	0.30	−2.1	4	8,289	s.	54	s.	30	22	6	3	2.4	0.0	0.0
Missouri Valley							60.3	+6.6										62	1.26	−0.6										3.4		
Columbia, Mo	784	11	84	29.31	30.15	+.10	61.4	+4.8	83	17	74	30	23	49	37	----	----	----	2.17	−0.2	6	4,863	se.	44	sw.	30	22	4	5	2.7	0.0	0.0
Kansas City	963	161	181	29.07	30.10	+.06	63.6	+5.9	83	16	74	39	23	54	30	53	46	60	1.01	−1.2	6	6,462	s.	48	sw.	30	24	4	3	2.5	0.0	0.0
St. Joseph	967	11	49	29.05	30.08	------	62.0	------	83	16	74	33	23	51	33	52	45	65	0.71	------	5	5,395	se.	30	w.	30	23	3	5	2.6	0.0	0.0
Springfield, Mo	1,324	98	104	28.74	30.14	+.09	63.7	+5.5	81	19	74	36	22	54	29	53	45	59	0.85	−2.0	3	6,749	se.	36	s.	30	25	3	3	1.7	0.0	0.0
Iola	984	11	50	29.05	30.09	+.05	62.4	+5.5	83	10	76	30	26	49	39	----	----	----	2.44	+0.2	6	4,066	se.	29	s.	30	23	6	2	2.1	0.0	0.0
Topeka	987	92	107	------	------	------	62.2	+5.2	83	17	74	33	23	50	33	----	----	----	0.66	−1.2	4	6,884	s.	38	sw.	30	22	6	3	2.6	0.0	0.0
Drexel	1,299	10	54	28.66	30.04	------	59.2	------	82	17	71	32	24	48	37	----	----	----	0.63	------	6	7,836	s.	40	sw.	30	13	11	7	4.4	0.0	0.0
Lincoln	1,189	11	84	28.78	30.04	+.01	61.8	+7.6	87	1	74	34	22	49	41	50	40	54	1.90	+0.1	3	7,526	se.	35	nw.	30	12	8	11	5.0	0.0	0.0
Omaha	1,105	115	122	28.88	30.06	+.03	61.4	+7.1	84	17	72	39	23	50	34	51	43	60	0.51	−1.8	5	4,494	s.	30	nw.	4	13	12	6	4.5	0.0	0.0
Valentine	2,598	47	54	27.25	29.96	−.05	56.2	+6.9	88	1	70	33	5	42	41	46	39	63	1.26	−0.1	4	7,894	w.	44	sw.	12	14	11	6	3.8	0.0	0.0
Sioux City	1,135	94	164	28.83	30.05	+.03	58.8	+7.9	84	18	70	35	6	48	35	50	43	64	1.05	−0.7	1	8,935	se.	45	w.	4	16	9	6	3.6	0.0	0.0
Huron	1,306	59	74	28.61	30.02	+.01	56.2	+8.5	87	1	69	36	6	44	44	47	41	68	1.49	+0.2	5	7,879	se.	33	s.	24	15	11	5	3.7	0.0	0.0
Pierre	1,572	70	75	28.30	29.96	−.05	57.1	+7.3	83	17	69	36	6	45	36	48	43	68	1.38	+0.6	5	7,145	e.	35	nw.	5	18	3	10	4.0	0.0	0.0
Yankton	1,233	49	57	28.69	30.01	.00	58.4	+7.3	86	1	71	36	22	46	41	----	----	----	0.41	−1.2	3	5,759	sw.	30	w.	4	13	10	8	4.2	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, October, 1924*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. +2 mean min. ÷3	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern Slope							**48.5**	**+3.2**										**64**	**1.42**	**+0.5**										**5.0**		
Billings	3,140	5					49.1		79	16	64	22	30	34	50				1.26		4											
Havre	2,505	11	44	27.28	29.92	−.06	49.0	+4.5	82	25	64	22	6	34	46	41	34	66	0.40	−0.1	5	5,099	sw.	42	sw.	30	14	9	8	4.0	1.1	0.0
Helena	4,110	87	112	25.76	29.97	−.06	47.1	+2.2	73	25	57	28	6	37	33	39	32	61	0.76	−0.1	9	5,766	sw.	37	sw.	12	10	9	12	5.6	0.8	0.0
Kalispell	2,973	48	56	26.89	29.95	−.06	44.7	+1.2	67	15	56	25	11	34	34	38	31	64	0.32	−0.8	5	3,713	nw.	19	sw.	30	12	7	12	5.4	0.0	0.0
Miles City	2,371	48	55	27.44	30.01	+.01	52.0	+5.5	79	25	64	30	6	40	38	43	37	65	1.21	+0.4	7	4,457	ne.	30	w.	31	15	5	11	4.4	T.	0.0
Rapid City	3,259	50	58	26.58	30.00	−.01	53.2	+4.7	78	16	65	30	6	42	39	44	36	59	2.62	+1.5	6	5,478	w.	36	sw.	12	14	8	9	4.5	T.	0.0
Cheyenne	6,088	84	101	24.00	29.96	−.05	47.8	+3.0	74	1	59	27	5	36	38	40	33	64	2.25	+1.5	7	10,058	w.	70	nw.	4	12	11	8	4.5	T.	0.0
Lander	5,372	60	68	24.65	30.02	−.02	45.5	+2.0	70	1	58	26	30	34	37	38	31	61	1.82	+0.8	8	3,553	sw.	38	w.	12	9	11	11	5.6	0.8	0.0
Sheridan	3,790	10	47	26.08	30.00		47.8		75	7	62	25	6	34	44	39	33	67	2.07		6	3,419	nw.	26	sw.	30	11	10	10	5.4	T.	0.0
Yellowstone Park	6,241	11	48	23.88	30.04	+.02	40.4	−1.1	66	25	50	24	11	31	34	34	29	70	2.43	+1.3	18	5,436	s.	40	sw.	31	7	8	16	6.6	11.7	0.0
North Platte	2,821	11	51	27.10	30.02	.00	56.8	+7.1	89	1	70	32	5	43	47	47	41	67	0.95	−0.2	5	5,534	se.	39	s.	11	16	6	9	4.2	0.0	0.0
Middle Slope							**60.1**	**+4.2**										**56**	**0.95**	**−0.6**										**3.2**		
Denver	5,292	106	113	24.72	29.96	−.05	54.4	+3.2	82	17	67	34	13	42	36	43	33	52	0.96	0.0	6	6,007	s.	46	w.	4	17	11	3	3.7	0.0	0.0
Pueblo	4,685	80	86	25.28	29.95	−.04	55.4	+3.4	86	1	72	30	13	38	47	42	32	49	0.51	−0.2	3	5,562	nw.	56	w.	11	16	13	2	4.0	T.	0.0
Concordia	1,392	50	58	28.57	30.05	+.02	61.5	+5.6	89	1	75	31	23	38	38	49	40	55	0.48	−1.5	4	6,159	s.	30	s.	4	10	15	6	4.5	0.0	0.0
Dodge City	2,509	11	51	27.46	30.06	+.04	59.4	+3.3	89	1	73	29	31	46	42	49	42	66	1.68	+0.3	4	7,392	se.	41	se.	11	21	7	3	2.3	T.	0.0
Wichita	1,358	139	158	28.63	30.06	+.03	63.4	+4.8	87	4	74	38	24	53	34	53	46	60	1.70	−0.6	5	10,049	s.	52	sw.	30	18	9	4	3.0	0.0	0.0
Broken Arrow	765	11	52	29.28	30.10		65.0		86	4	78	35	23	52	34				0.04		2	8,357	se.	48	s.	30	22	6	3	2.5	0.0	0.0
Muskogee	652	4					66.0		89	4	81	32	26	51	42				0.94		4		se.				20	9	2		0.0	0.0
Oklahoma City	1,214	10	47	28.81	30.08	+.05	66.3	+4.8	90	4	79	37	23	54	34	53	45	57	0.38	−1.4	2	7,143	s.	34	s.	30	19	8	4	2.6	0.0	0.9
Southern Slope							**64.4**	**+1.2**										**60**	**0.68**	**−1.1**										**2.8**		
Abilene	1,738	10	52	28.26	30.06	+.05	66.6	+1.2	92	4	79	33	24	54	37	54	48	62	0.30	−2.0	4	6,442	s.	32	s.	2	21	6	4	2.3	0.0	0.0
Amarillo	3,676	10	49	26.33	30.04	+.04	60.0	+2.3	88	1	73	33	31	47	44	49	43	67	0.86	−0.8	6	8,320	se.	32	w.	30	12	16	3	3.9	0.0	0.0
Del Rio	944	64	71	29.05	30.03	+.05	70.8	+0.8	88	4	81	45	24	61	32				1.14	−0.9	1	5,676	se.	25	n.	21	19	8	4	3.1	0.0	0.0
Roswell	3,566	75	85	26.40	29.99	+.03	60.2	+0.7	89	1	76	32	31	44	47	47	36	50	0.41	−0.8	3	5,851	s.	31	se.	10	23	7	1	1.9	0.0	0.0
Southern Plateau							**60.2**	**+0.2**										**41**	**0.18**	**−0.4**										**1.5**		
El Paso	3,762	110	133	26.22	29.93	+.01	66.8	+3.3	87	10	79	45	31	54	37	50	35	36	0.24	−0.7	2	7,755	e.	36	sw.	29	26	4	1	1.5	0.0	0.0
Santa Fe	7,013	38	53	23.30	29.98	+.02	51.2	+0.8	75	1	64	27	31	38	37	38	26	44	0.30	−0.8	1	5,445	se.	30	w.	7	22	7	2	2.2	T.	0.0
Flagstaff	6,907	10	59	23.38	29.97	+.05	44.8	+0.1	72	1	62	18	31	28	46	34		54	2.04		3	6,656	sw.	40	sw.	29	25	5	1		T.	0.0
Phoenix	1,108	10	82	28.76	29.90	+.02	71.2	+0.6	99	1	88	44	12	54	46	54	41	39	0.30	0.0	1	3,418	e.	20	w.	10	27	4	0	1.0	0.0	0.0
Yuma	141	9	54	29.75	29.90	+.03	70.2	−3.1	101	1	88	44	11	53	46	54	41	42	0.00	−0.2	0	3,710	w.	28	w.	29	29	2	0	0.6	0.0	0.0
Independence	3,957	5	25	25.97	30.00	+.05	57.0	−0.5	87	1	73	24	30	41	41	42	23	31	0.06	−0.3	2	5,639	nw.	39	w.	16	29	2	0	2.0	0.0	0.0
Middle Plateau							**49.6**	**−0.6**										**48**	**1.08**	**+0.3**										**4.2**		
Reno	4,532	74	81	25.45	29.96	−.03	50.6	+0.9	77	1	64	28	12	38	43	40	30	51	1.44	+1.1	7	5,068	w.	39	w.	28	16	10	5	3.6	3.8	0.0
Tonopah	6,090	12	20				50.0		75	1	60	24	30	40	28	37	23	41	0.06		2		se.								0.0	0.0
Winnemucca	4,344	18	56	25.61	30.01	−.04	47.0	−1.3	75	15	63	24	4	31	49	37	27	53	0.46	−0.1	8	5,644	sw.	48	sw.	28	11	9	11	5.2	0.2	0.0
Modena	5,479	10	43	24.63	29.99	+.03	45.5	−2.5	78	1	64	11	30	27	48	34	19	40	0.41	−0.4	2	8,436	w.	70	sw.	29	18	8	5	3.0	1.6	T.
Salt Lake City	4,360	163	203	25.62	29.99	−.02	52.4	−0.1	77	16	62	32	29	42	30	42	32	52	1.87	+0.5	7	5,305	s.	48	n.	29	14	3	14	5.2	1.0	0.0
Grand Junction	4,602	60	68	25.40	29.99	.00	52.6	−0.2	78	17	66	32	30	40	34	41	30	48	1.21	+0.3	7	4,637	se.	44	s.	10	13	13	5	3.9	1.1	0.0
Northern Plateau							**51.2**	**+1.4**										**59**	**1.25**	**0.0**										**6.1**		
Baker	3,471	48	53	26.42	30.01	−.07	47.4	+0.8	72	15	58	28	4	37	36	41	34	64	0.32	−0.6	5	5,480	se.	29	nw.	10	6	6	19	6.7	0.6	0.0
Boise	2,739	78	86	27.15	30.01	−.05	52.8	+1.7	78	15	63	32	4	42	34	44	33	52	1.50	+0.2	7	4,444	se.	25	se.	28	8	12	11	5.8	0.0	0.0
Lewiston	757	40	48	29.16	29.97	−.10	53.6	+2.1	78	15	66	35	18	42	38				1.39	+0.2	8	2,075	e.	30	nw.	28	5	11	15	6.7	0.0	0.0
Pocatello	4,477	60	68	25.47	30.00	−.04	48.6	+0.2	71	15	59	28	4	38	38	40	32	58	1.84	+0.9	12	6,545	s.	36	s.	28	10	7	14	5.6	T.	0.0
Spokane	1,929	101	110	27.91	29.97	−.09	49.8	+1.5	74	15	60	31	11	40	34	43	36	63	1.10	−0.4	7	4,312	sw.	25	sw.	2	7	10	14	6.3	0.0	0.0
Walla Walla	991	57	65	28.90	29.97	−.10	55.3	+1.8	81	15	65	35	10	46	33	47	39	58	1.35	−0.1	9	3,753	s.	30	s.	28	10	11	10	5.4	0.0	0.0
North Pacific Coast Region							**53.1**	**+1.0**										**82**	**6.98**	**+3.2**										**6.6**		
North Head	211	11	56	29.69	29.92	−.13	53.2	+0.3	68	20	57	42	30	49	16	51	49	89	7.62	+3.7	21	15,543	s.	83	s.	28	1	9	21	8.1	0.0	0.0
Port Angeles	29	8	53		29.92		50.0		65	23	57	35	11	43	22				3.31	+0.7	18	3,743	s.	36	w.	2	3	12	16		0.0	0.0
Seattle	125	215	250	29.83	29.96	−.09	52.8	+1.4	67	15	58	37	10	47	22	49	46	82	5.03	+2.4	17	7,690	se.	47	s.	30	2	11	18	8.0	0.0	0.0
Tacoma	194	172	201	29.74	29.95	−.09	52.6	+2.1	69	22	59	37	10	46	26				4.88	+1.7	19	6,512	s.	42	s.	15	1	14	16	7.8	0.0	0.0
Tatoosh Island	86	9	53	29.78	29.88	−.13	51.8	+1.9	62	20	55	42	31	48	11	50	49	92	12.05	+4.0	22	13,096	e.	78	sw.	30	1	14	18	7.4	0.0	0.0
Yakima	1,071	5					50.3		74	22	65	26	9	36	42				1.03		8						4	9	15	6.2	T.	0.0
Medford	1,425	4					52.2		80	20	64	25	12	40	41	45	40	70	4.89		11		n.				8	8	24		0.0	0.0
Portland, Oreg	153	68	106	29.80	29.96	−.10	54.6	+0.4	71	6	61	37	10	48	27	50	47	78	5.50	+2.2	19	4,288	s.	32	s.	29	4	3	21	8.2	0.0	0.0
Roseburg	510	9	57	29.46	30.01	−.07	53.8	−0.1	77	24	63	34	11	44	31	50	47	79	10.46	+7.8	17	2,224	s.	28	sw.	28	3	7	12	6.4	0.0	0.0
Middle Pacific Coast Region							**57.5**	**−2.2**										**74**	**3.57**	**+2.1**										**4.3**		
Eureka	62	73	89	29.98	30.05	−.01	54.4	−0.9	73	14	60	38	11	48	21	51	49	83	6.84	+4.2	19	5,811	se.	40	sw	28	8	10	13	5.9	0.0	0.0
Point Reyes	490	7	18	29.47	29.99		54.0	−0.7	74	19	58	45	29	50	24				3.32		12	15,238	nw.	61	s.	5	12	10	9	4.9	0.0	0.0
Red Bluff	332	50	56	29.64	30.00	−.03	59.2	−5.1	90	2	68	37	11	50	29	52	45	66	4.22	+2.6	9	5,008	s.	32	se.	28	12	10	7	4.4	0.0	0.0
Sacramento	69	106	117	29.94	30.01	+.02	59.5	−3.4	88	2	69	42	11	50	27	53	47	69	2.10	+1.1	7	5,149	s.	31	nw.	9	12	12	5	3.3	0.0	0.0
San Francisco	155	208	243	29.86	30.03	+.02	59.4	−1.1	83	2	66	48	12	53	25	53	50	76	2.98	+1.7	10	6,010	w.	38	nw.	9	20	6	6	3.9	0.0	0.0
San Jose	141	12	110	29.90	30.05		58.5	−1.8	88	2	70	36	12	47	40				1.72	+0.8	8	4,600	s.	27	sw.	20	19	6	5	3.5	0.0	0.0
South Pacific Coast Region							**61.0**	**−2.6**										**68**	**0.64**	**−0.2**										**2.9**		
Fresno	327	89	98	29.66	30.02	+.06	61.9	−2.1	90	3	74	40	11	50	34	52	43	57	0.64	−0.1	5	4,179	nw.	24	nw.	15	21	9	1	2.1	0.0	0.0
Los Angeles	338	159	191	29.64	30.00	+.05	62.6	−2.7	89	19	72	46	11	53	34	53	48	68	0.63	−0.1	3	3,663	sw.	27	sw.	10	20	6	4	3.5	0.0	0.0
San Diego	87	62	70	29.90	29.99	+.04	60.5	−3.2	79	19	67	49	12	54	23	55	52	78	0.35	−0.1	2	4,510	nw.	28	w.	10	16	11	3	2.9	0.0	0.0
San Luis Obispo	201	32	40	29.82	30.04	+.05	59.2	−2.6	91	2	71	40	13	47	40	50	45	69	0.94	−0.4	6	3,257	nw.	24	w.	9	21	7				
West Indies																																
San Juan, P. R	82	9	54	29.82	29.90		79.6	−0.2	92	22	85	72	5	74	16				5.66	−0.4	18	6,730	e.	44	ne.	2	5	20	6	5.4	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.73	29.85	+.02	78.6	−1.2	87	1	84	70	23	73	14	75	74	91	12.55	+4.7	24	4,502	s.	27	s.	23	0	13	17	7.8	0 0	0.0
Colon	36	7	97	29.82	29.86	+.02	81.9	+1.7	92	16	89	72	20	75	18	76	75	90	9.00	−3.4	21	4,630	se.	29	s.	1	1	10	19	7.9	0.0	0.0
Alaska																																
Juneau	80	11	54				42.2		54	22	47	30		8 3	17	39	37	87	12.74		24	5,895	s.	36	s.	10	2		227	9.2	T·	0 0

TABLE II.—*Data furnished by the Canadian Meteorological Service, October, 1924*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*In.*	*In.*	*In.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48												
Halifax, N. S.	88	29.90	30.01	+0.01	49.4	+2.2	58.1	40.7	70	27	3.62	−1.93	0.0
Yarmouth, N. S.	65	29.92	29.99	−.03	48.5	+0.9	55.6	41.4	70	26	3.54	−1.16	0.0
Charlottetown, P. E. I.	38	29.93	29.97	+.01	47.9	+1.4	54.1	41.8	65	31	0.68	−4.22	0.0
Chatham, N. B.	28	29.91	29.93	−.03	45.6	+2.6	56.7	34.5	72	20	0.42	−3.44	0.2
Father Point, Que.	20	30.02	30.04	+.09	37.5	−2.3	45.9	29.1	68	14	1.78	−1.12	0.0
Quebec, Que.	296	29.80	30.13	+.13	46.3	+3.9	54.1	38.6	68	24	1.55	−2.60	2.0
Montreal, Que.	187	29.94	30.15	+.14	48.3	+3.5	55.6	41.1	69	30	0.42	−2.71	T.
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.90	30.17	+.16	49.5	+5.7	62.3	36.8	76	28	0.40	−2.15	T.
Kingston, Ont.	285	29.88	30.19	+.16	50.2	+3.2	58.6	41.9	72	33	0.30	−2.43	0.0
Toronto, Ont.	379	29.80	30.21	+.17	50.6	+4.0	60.8	40.4	72	31	0.61	−1.75	0.0
Cochrane, Ont.	930				43.5		53.7	33.3	75	16	0.90		0.0
White River, Ont.	1,244	28.80	30.13	+.15	42.8	+5.7	56.2	29.3	69	14	1.03	−1.32	T.
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.48			49.6	+3.5	59.0	40.1	70	31	0.58	−2.59	0.0
Parry Sound, Ont.	688	29.49	30.19	+.18	48.9	+5.0	59.2	38.6	73	29	0.76	−3.16	0.0
Port Arthur, Ont.	644	29.38	30.10	+.12	47.5	+7.6	55.3	39.7	64	26	2.75	+0.19	0.0
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.10	29.92	−.05	46.6	+8.8	57.1	36.1	74	28	2.17	+0.97	1.1
Le Pas, Man.	860				44.5		56.3	32.7	68	18	1.16		T.
Qu'Appelle, Sask.	2,115	27.62	29.86	−.11	46.8	+7.4	58.1	35.6	76	20	2.05	+0.95	8.0
Medicine Hat, Alb.	2,144	27.58	29.85	−.12	49.4	+4.6	61.1	37.7	79	26	0.80	+0.22	0.0
Moose Jaw, Sask.	1,759				48.1		61.0	35.3	76	19	1.46		0.5
Swift Current, Sask.	2,392	27.35	29.88	−.09	46.4	+4.3	58.5	34.4	78	16	2.76	+1.88	0.0
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150	27.52	29.80	−.13	43.6	+2.5	55.7	31.5	69	20	1.21	+0.51	5.2
Prince Albert, Sask.	1,450	28.32	29.90	−.07	45.4	+8.3	56.5	34.4	68	24	1.73	+0.90	1.2
Battleford, Sask.	1,592	28.12	29.86	−.11	45.5	+5.9	57.5	33.5	72	16	0.72	+0.27	0.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.65	29.90	−.11	51.4	+2.2	56.7	46.2	64	40	3.10	+0.73	0.0

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Battleford, Sask.	1,592												
Kamloops, B. C.	1,262	28.65	29.93	−.04	60.4	+3.0	72.6	48.2	89	35	0.86	+0.1	0.0
Barkerville, B. C.	4,180	25.62	29.90	−.08	45.9	−0.8	54.9	37.0	71	22	4.12	+1.21	1.2
Calgary, Alb.	3,428	26.36	29.89	−.03	55.2	+5.4	71.3	39.1	86	26	1.26	−0.10	0.1
Winnipeg, Man.	760	29.15	29.98	+.04	54.3	+1.8	65.9	42.8	85	28	3.64	+1.61	0.0
St. Johns, N. F.	125	29.84	29.97	.00	55.9	+1.9	63.4	48.5	78	38	4.01	+0.30	0.0

(Plotted by Wilfred P. Day.)

(Plotted by Wilfred P. Day.)

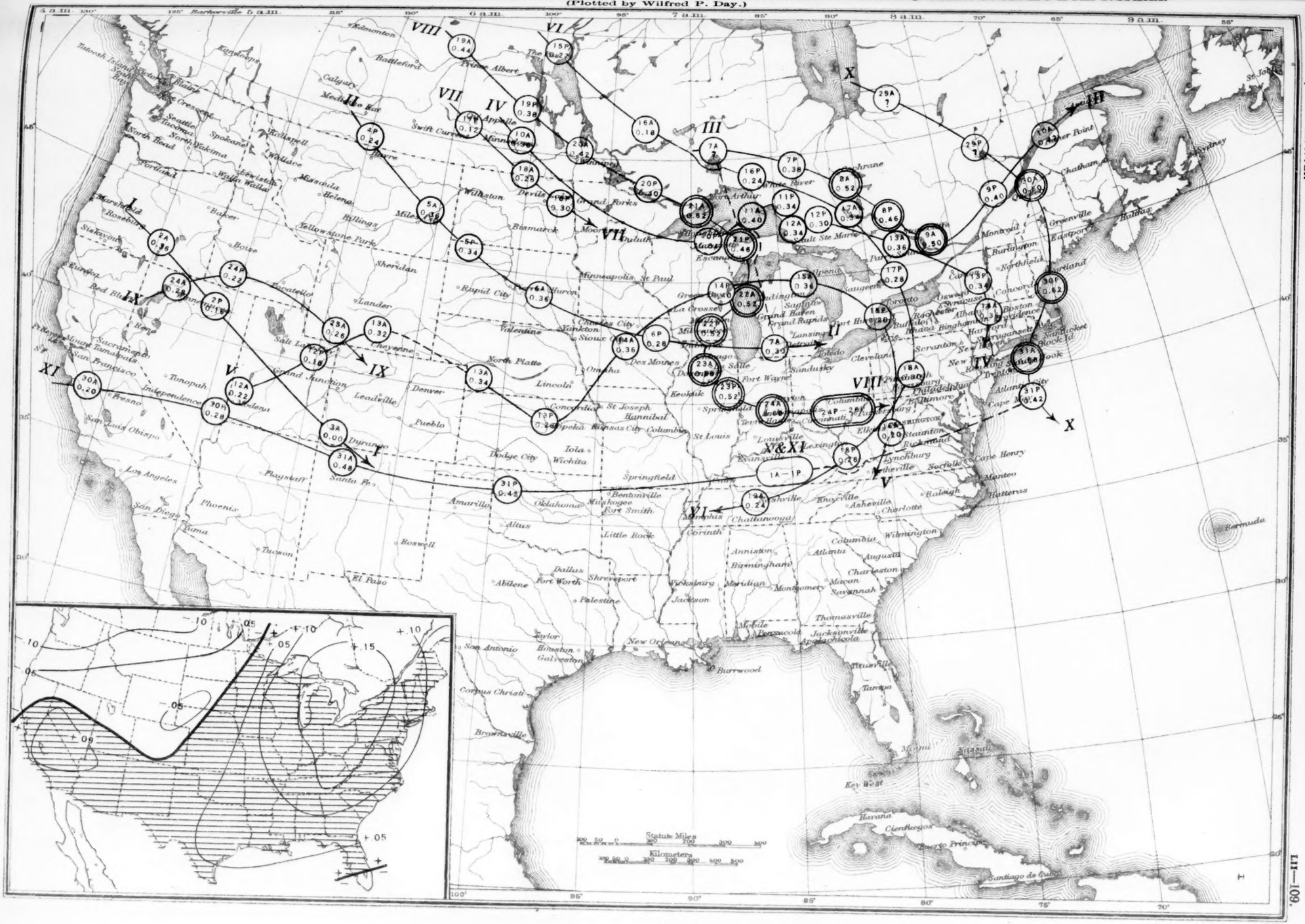


Chart II. Tracks of Centers of Cyclones, October, 1924. (Inset) **Change in Mean Pressure from Preceding Month.**

(Plotted by Wilfred P. Day.)

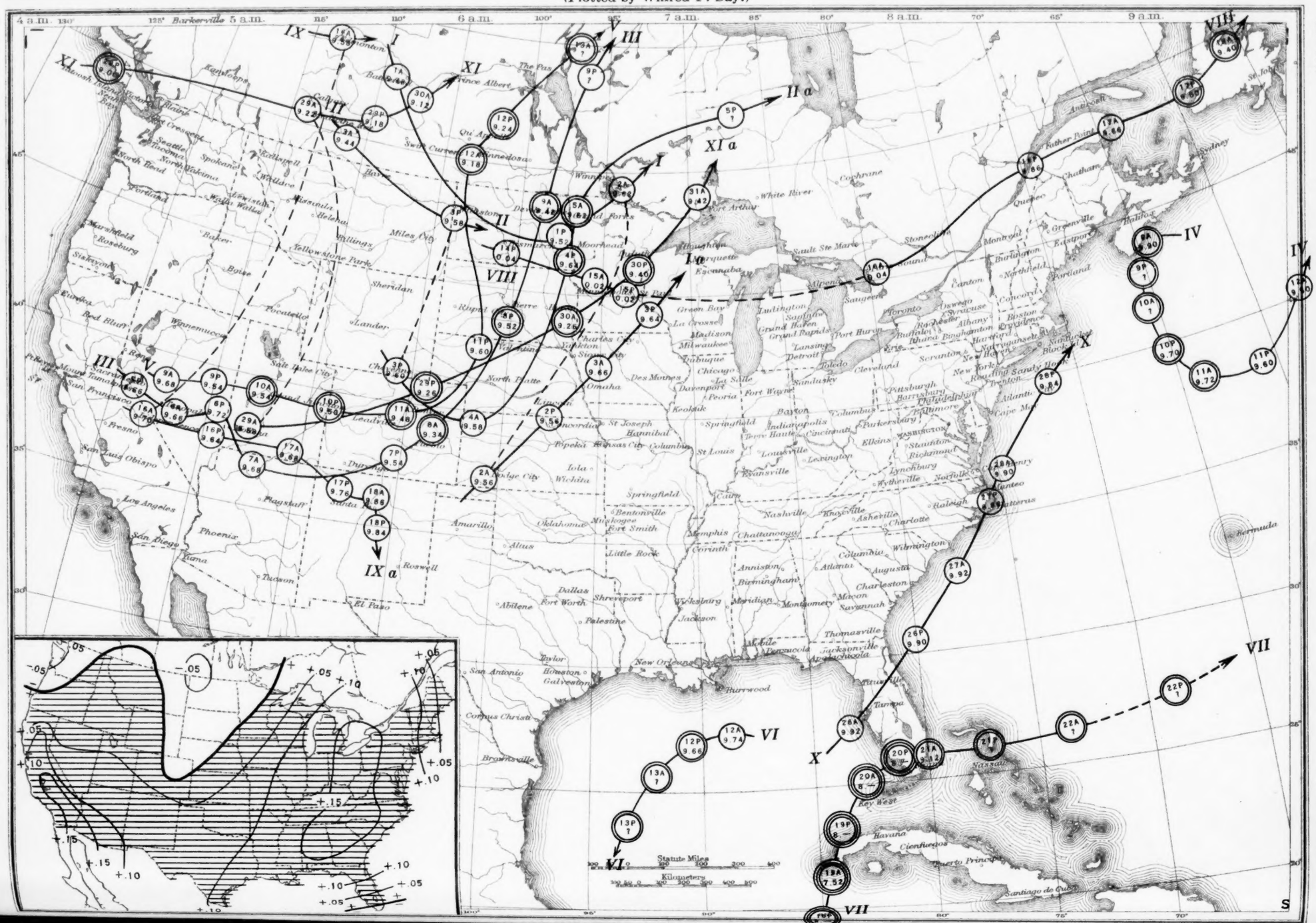


Chart III. Departure (°F.) of the Mean Temperature from the Normal, October, 1924.

Chart III. Departure (°F.) of the Mean Temperature from the Normal, October, 1924.

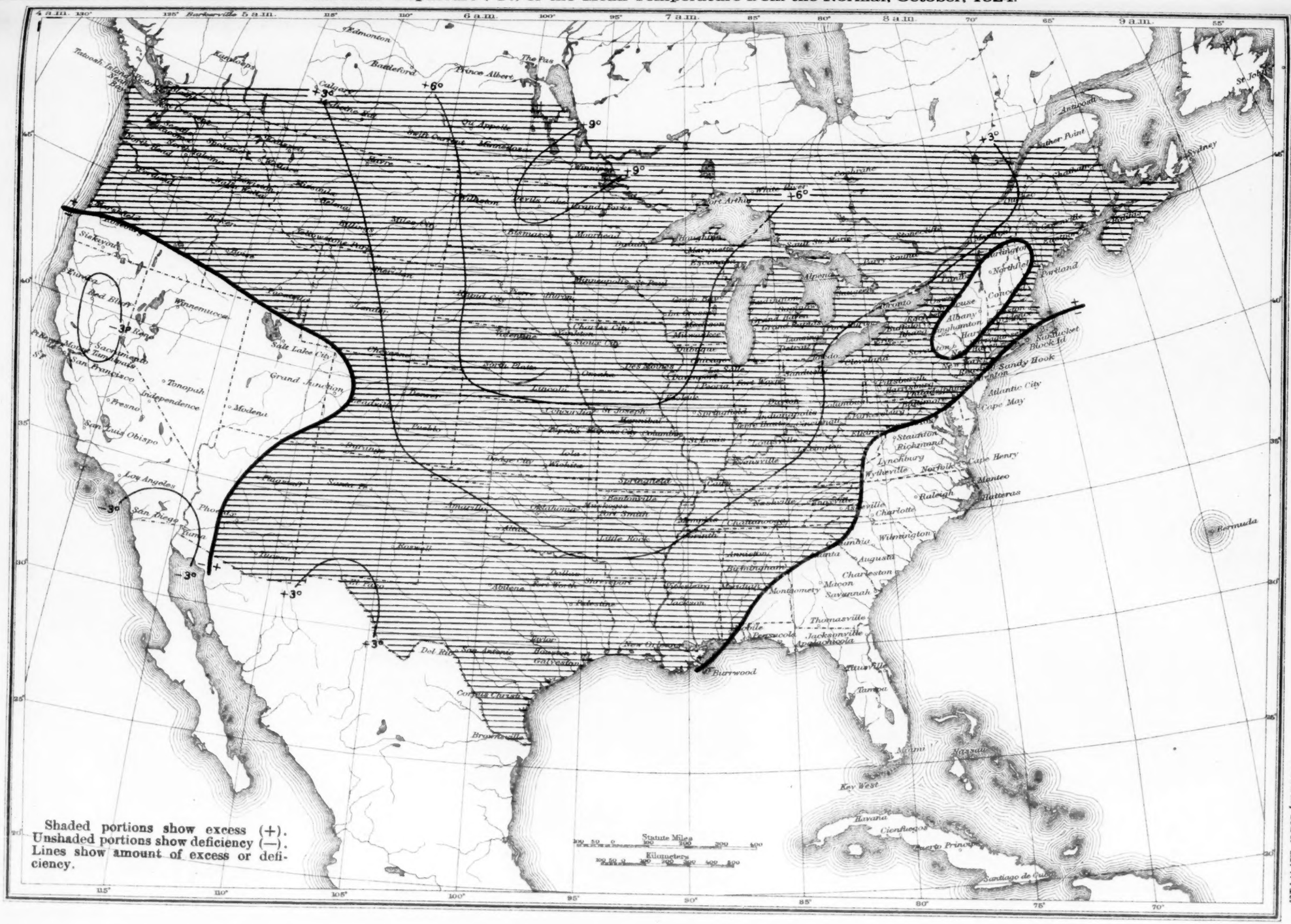

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart IV. Total Precipitation, Inches, October, 1924. (Inset) Departure of Precipitation from Normal.

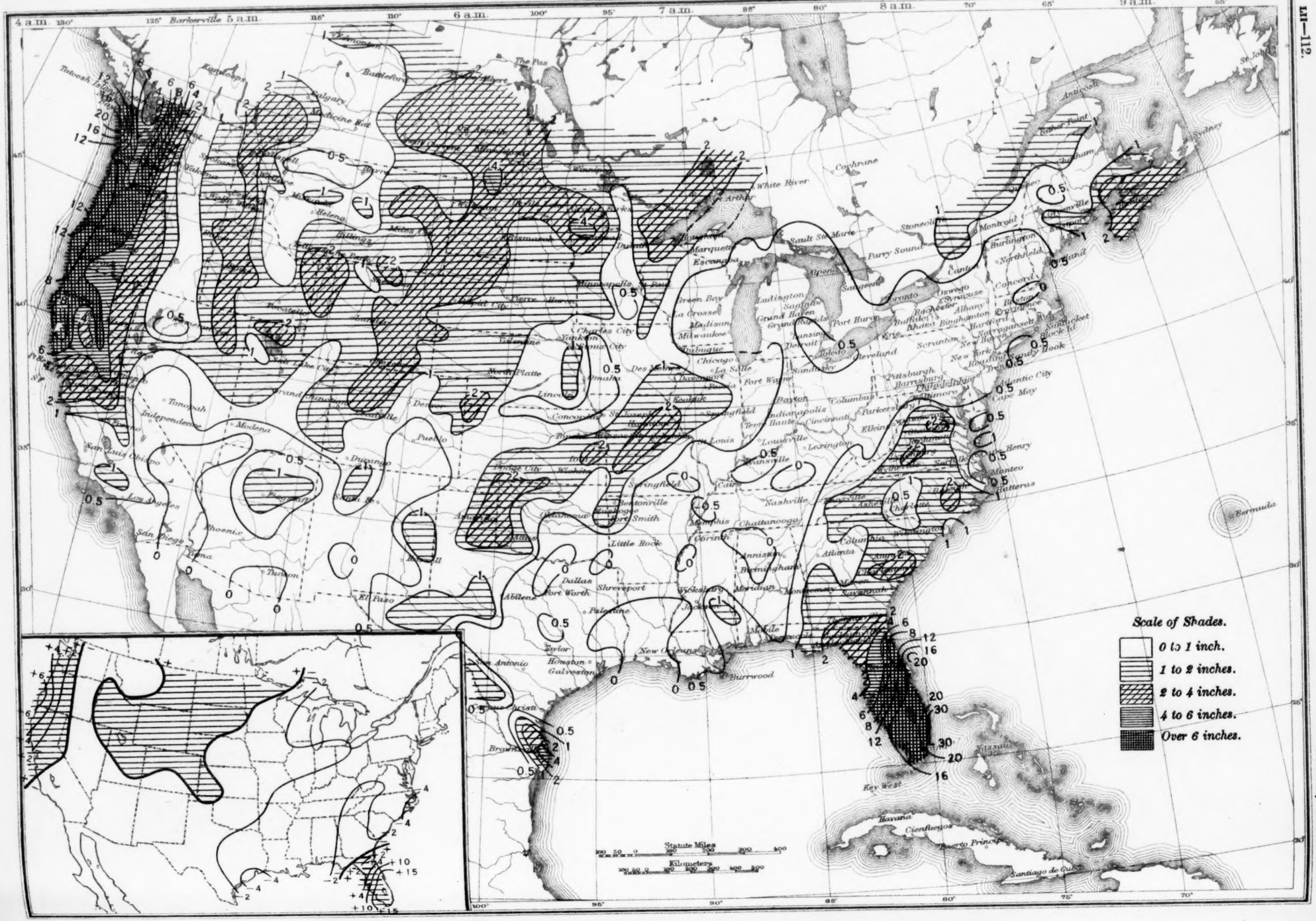


Chart V. Percentage of Clear Sky between Sunrise and Sunset, October, 1924.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, October, 1924.

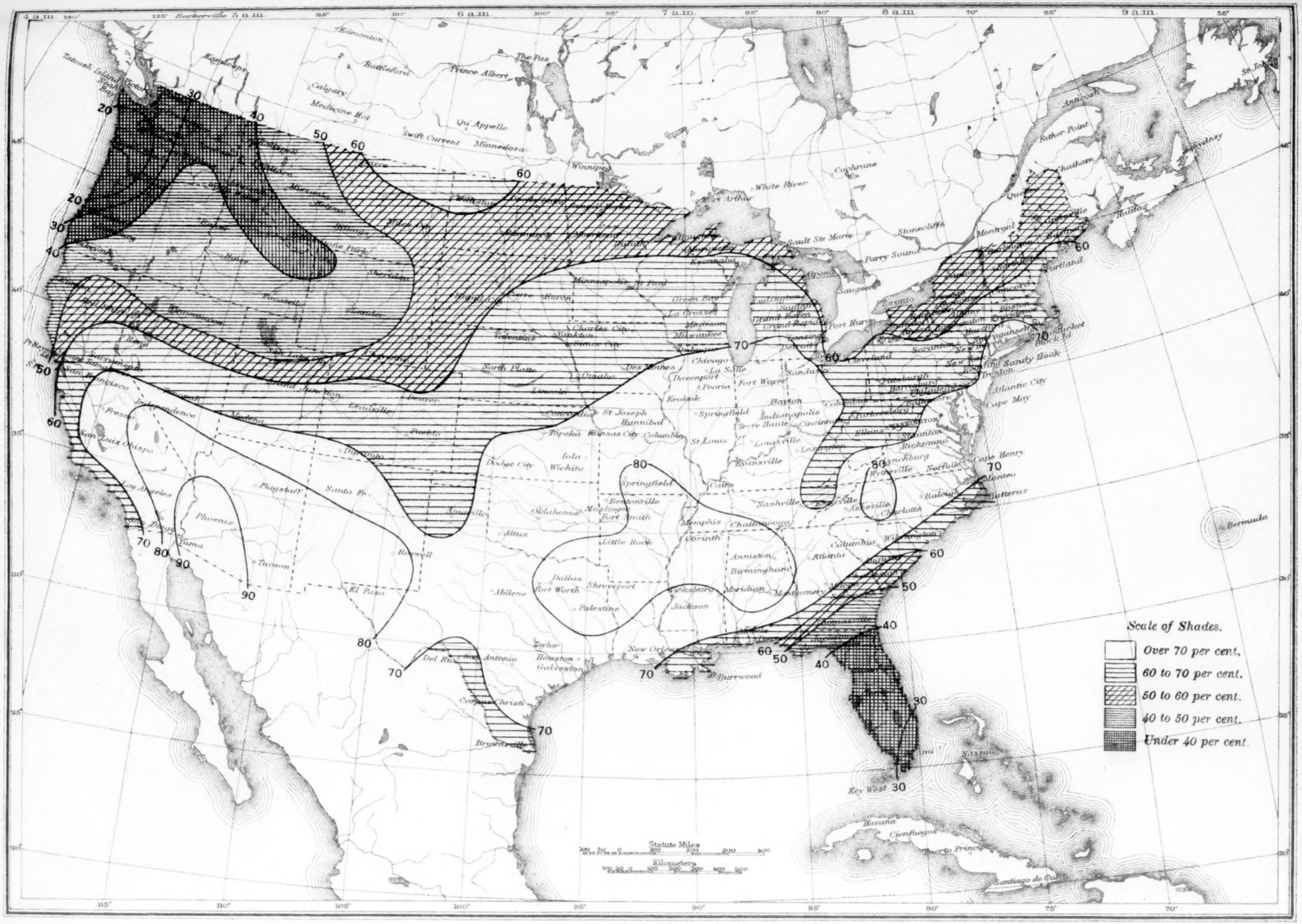
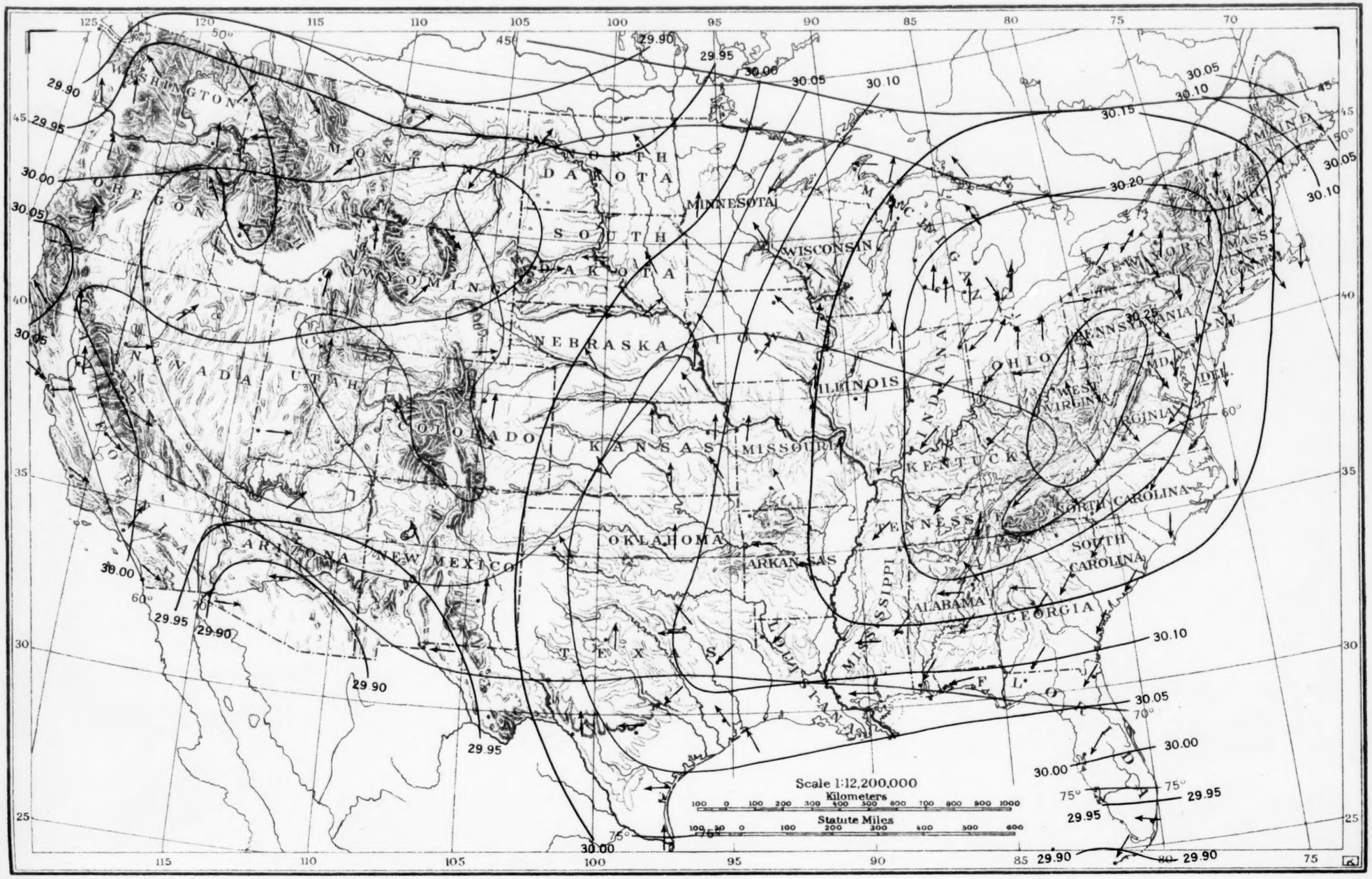


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, October, 1924.



(Plotted by F. A. Young.)

(Plotted by F. A. Young.)

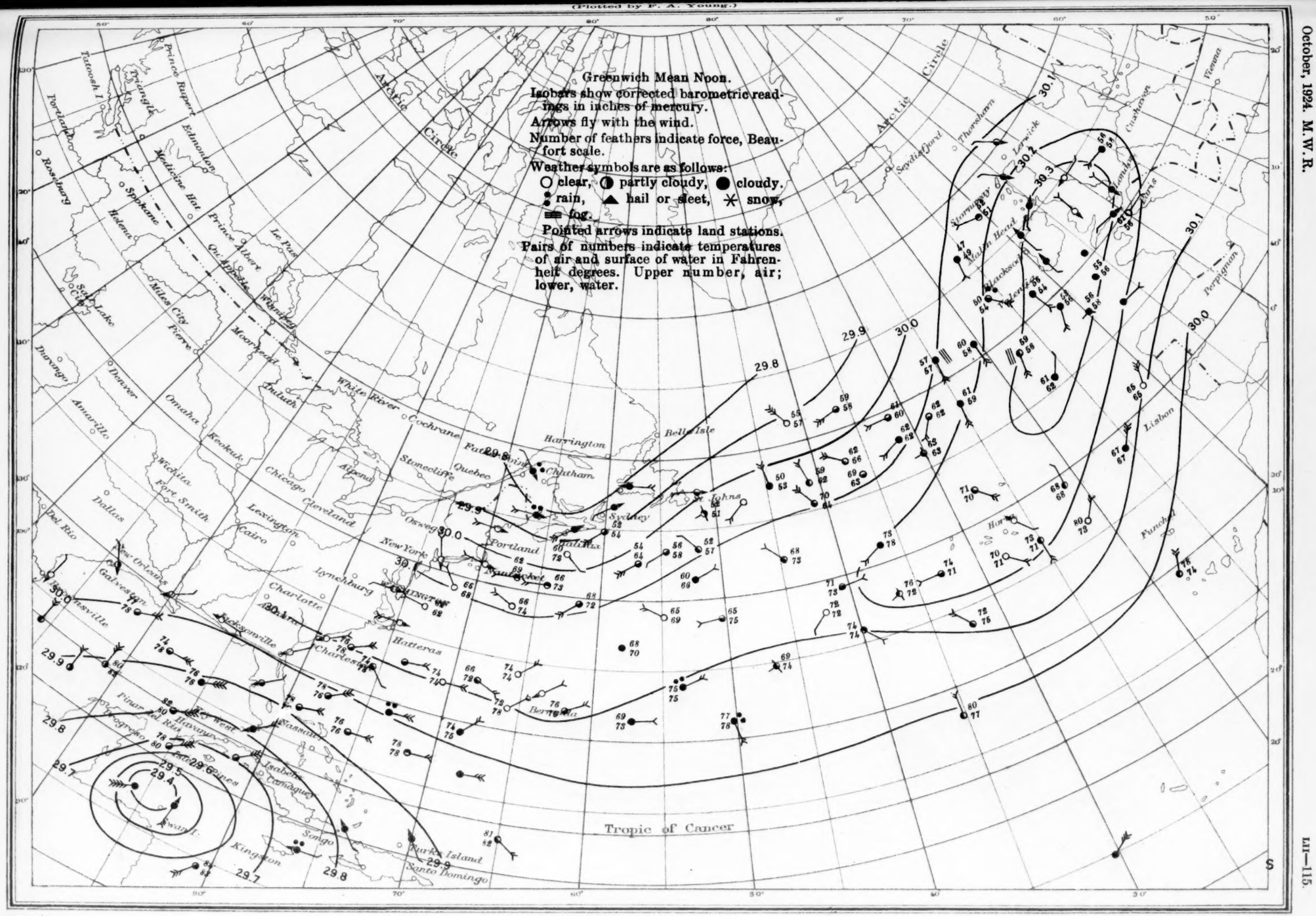
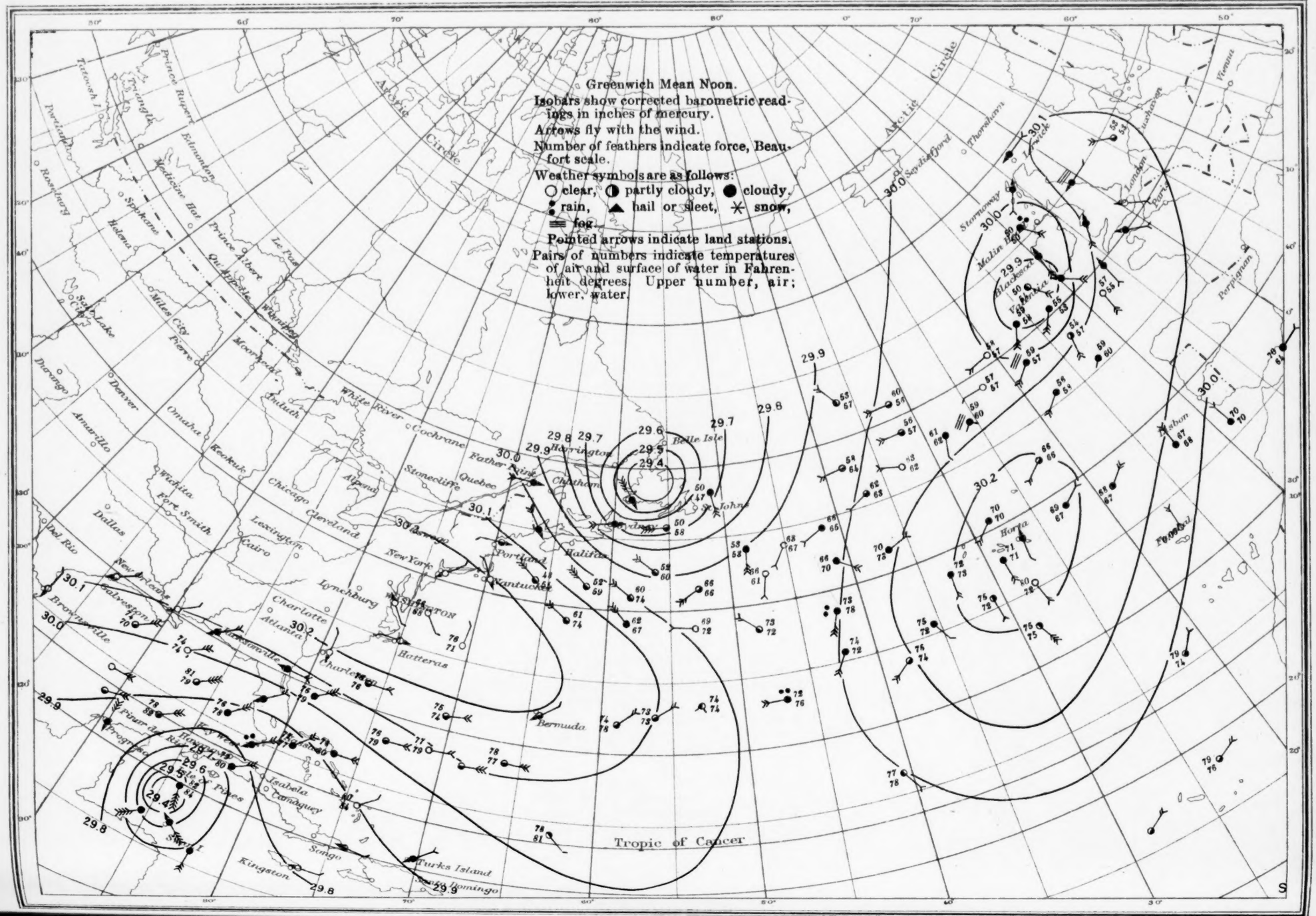


Chart IX. Weather Map of North Atlantic Ocean, October 18, 1924

(Plotted by F. A. Young.)



(Plotted by F. A. Young.)

(Plotted by F. A. Young.)

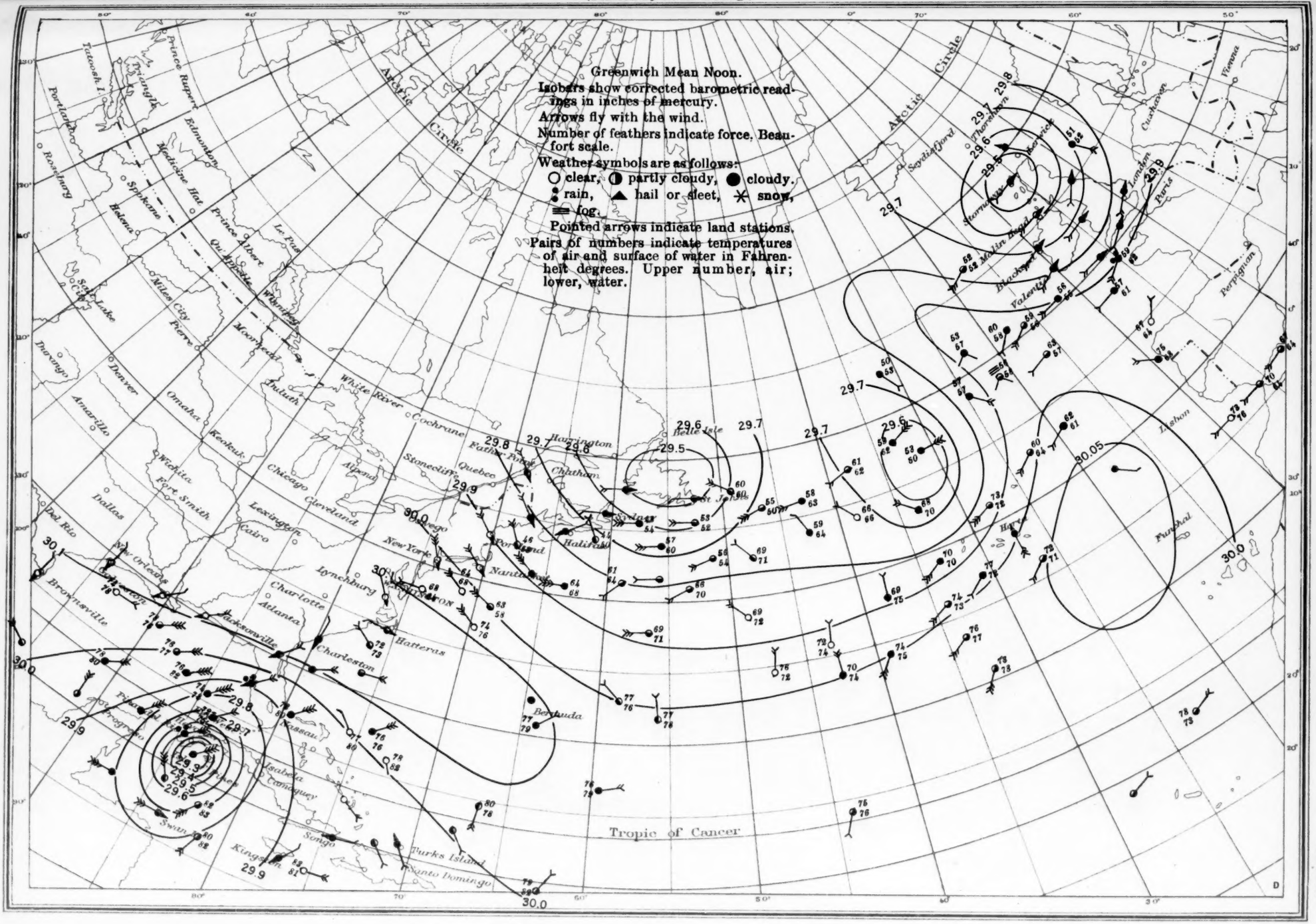


Chart XI. Weather Map of North Atlantic Ocean, October 20, 1924

(Plotted by F. A. Young.)

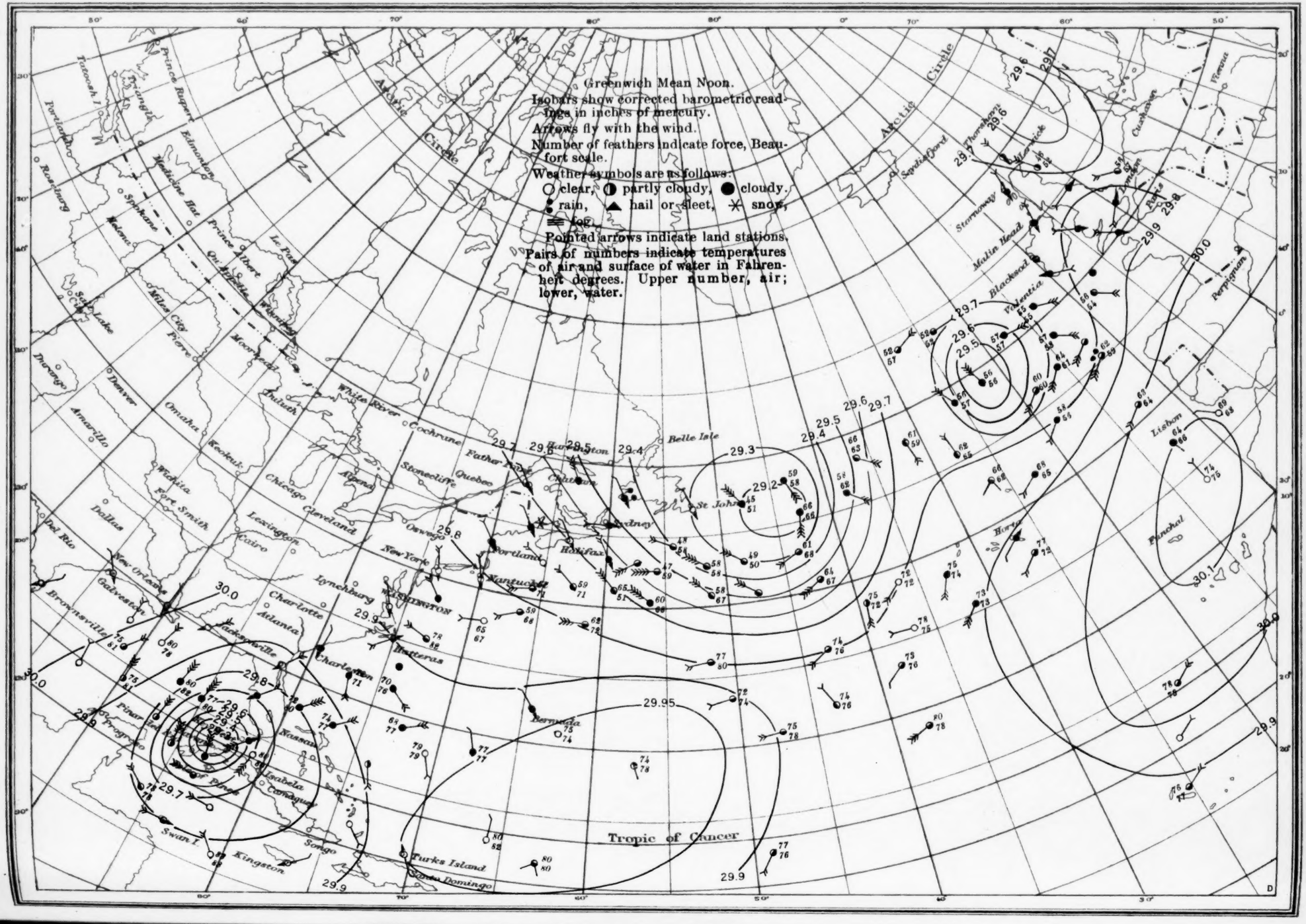


Chart XI. Weather Map of North Atlantic Ocean, October 21, 1924
(Plotted by F. A. Young.)

Chart XII. Weather Map of North Atlantic Ocean, October 21, 1924

(Plotted by F. A. Young.)

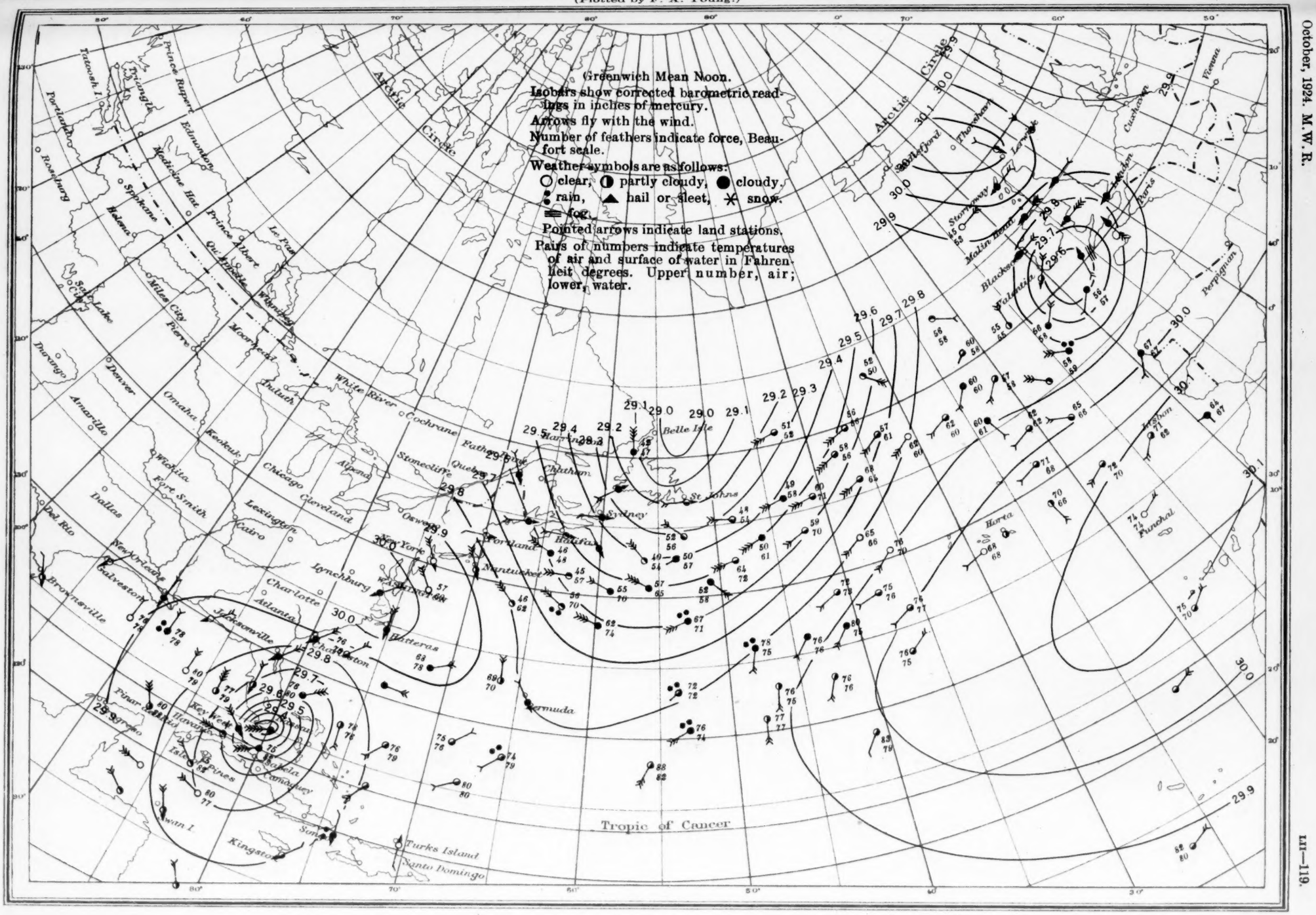
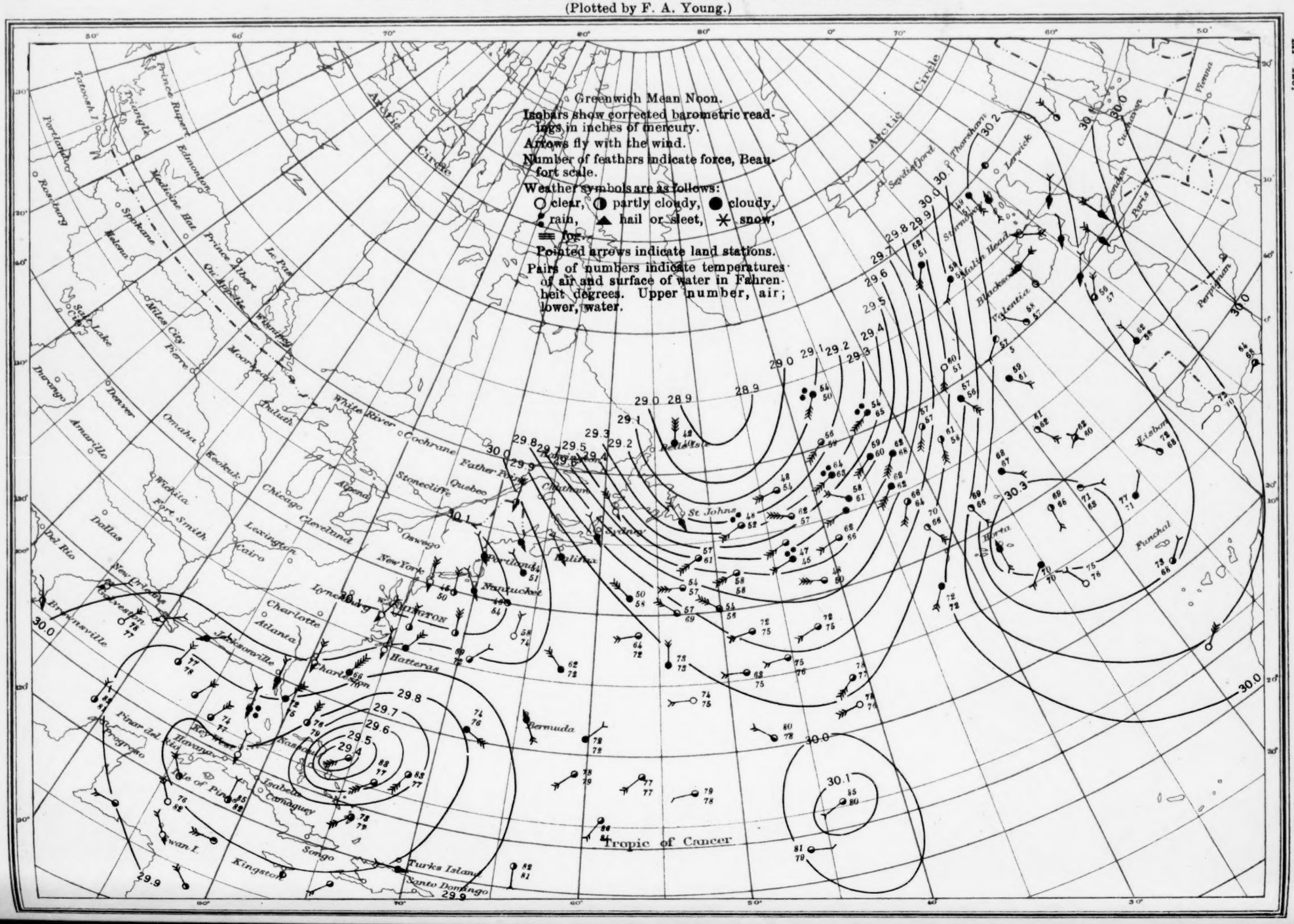


Chart XIII. Weather Map of North Atlantic Ocean, October 22, 1924

(Plotted by F. A. Young.)